RADIO-TELEGRAPHIST'S GUIDE AND LOG-BOOK

W. H. MARCHANT

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THE RADIO-TELEGRAPHIST'S GUIDE AND LOG-BOOK

THE RADIO-TELEGRAPHIST'S GUIDE AND LOG-BOOK

A MANUAL OF WIRELESS TELEGRAPHY FOR THE USE OF OPERATORS

BY

W. H. MARCHANT

WITH NINETY ILLUSTRATIONS

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PREFACE

The preface of a book the author believes is seldom read by anyone but the reviewer. As, however, it affords an opportunity to say a few words as to the nature and scope of the work, and to thank those who have kindly assisted him, the writer conforms to custom. In the first place the book is not intended for that class of person known as the "man in the street," who through curiosity may desire to know the how and why of Wireless Telegraphy. The object which the writer kept before him was to produce a book which would be of service to those engaged in the practical manipulation of Radio-Telegraph apparatus and who already possess some knowledge of electrical science.

The first portion of the book is devoted to a description of the various pieces of apparatus which go to make up a Radio-Telegraph installation and to the principles which guide in their construction and erection. Following this will be found a description of some of the leading systems. The author has selected the Marconi and United Wireless Co.'s systems as being representative of the ordinary spark method of generating electrical oscillations; the Poulsen system as representing the Arc method, and the Lepel and Telefunken systems to represent the newer quenched spark method. This section of the book is fully illustrated, many of the illustrations appearing for the first time. In the next chapter a description will be found of Mr S. G.

Brown's Telephone Relay, with which the author has obtained some remarkable results. Chapter VII. is devoted to measurements, the apparatus needed for and method of carrying out all the more important measurements being described. Chapter VIII. gives the regulations and instructions for the working of ships and stations licensed by the Postmaster-General, and is followed by Appendices, giving the International and American Morse Codes, Time Signals, List of Stations, and various other information which it is hoped will prove useful to the operator. At the back of the book will be found an entirely novel feature, I refer to the Log Sheets, which will enable the operator conveniently to keep a record of his voyages and working: it is thought that this will meet a need and will be appreciated. Finally the author desires to sincerely thank the following gentlemen and companies for assistance rendered:—S. G. Brown, Esq., for information relating to his Telephone Relay; the Topical Press Agency for illustrations of the Marconi and Poulsen systems; Messrs Siemens Bros. & Company for illustrations and particnlars relating to the new Telefunken system; Baron Egbert von Lepel, the Anglo-German Syndicate and B. Binyon, Esq., for some of the illustrations used in the description of the Lepel system; A. H. Morse, Esq., for illustration of the United Wireless Company's installation at Seward, and Robert Humfrey, Esq., who assisted in many ways, and to whom the Author is under many obligations.

W. H. M.

LONDON, 1912.

CONTENTS

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER IV

CHAPTER V

RADIO-TELEGRAPHIST'S GUIDE AND LOG-BOOK

CHAPTER I

HERTZIAN WAVES

In Hertzian-wave or Radio Telegraphy we are concerned with operations carried on in an infinitely tenuous medium termed the æther, which fills all space and permeates all matter. In order that a wave motion may be set up in any medium it is necessary that it should be endowed with elasticity —that is to say, with the ability to restore itself to its former condition after any force which causes a strain or distortion in it is withdrawn. Also it should possess inertia. As is well known, sound is due to a disturbance in the air, and if, say, a tuning-fork is caused to vibrate, the air in its neighbourhood will be carved into waves of alternate compression and rarefaction which will travel outward from the source at a rate depending on the ratio of the square root of the elasticity of the medium to its density, in the case of air at atmospheric pressure the waves travel at a speed of about 1090 feet per second.

The distance between one place of maximum compression and the next is termed the wave length of the sound, and is determined by the rate at which the source of the sound vibrates and on the velocity with which the disturbance is transmitted through the medium. We have seen that the presence of a vibrat-

ing mechanical body, such as a tuning-fork, immersed in a suitable medium (the air) will carve the medium into waves, and if suitable means are provided (the human ear) the presence of these waves can be detected at a distance. In the same way a vibrating electrical circuit will set up, in the æther, waves of alternating electric strain which are propagated outward at a speed depending on the elasticity and density of the medium. The velocity of electric waves is about 186,000 miles per second, the same

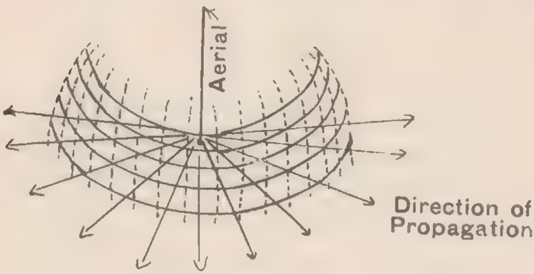

FIG. 1

Dotted lines = electric component
Continuous = magnetic component

speed at which light travels. This fact has led to the assumption that both light and electric waves are identical in nature and that both are undulations in the same medium, differing only in wave length; like light the electric waves can be refracted, reflected and diffracted, as was experimentally demonstrated by Hertz.

The vibration of particles producing sound waves consists of a to-and-fro movement in the direction of propagation, but the æther is not competent to sustain a wave motion of this kind. In the case of æther waves the medium is displaced in a direction at right angles to the direction of propagation, and the electric

and magnetic components of which it is made up are also at right angles to each other and to the direction of propagation (Fig. 1).

We shall now consider the means by which these æther waves may be set up and also the means adopted to detect them at a distance, as, unlike sound waves, they are not directly apprehensible by the senses.

It has been experimentally demonstrated that if a condenser is charged, and then discharged by means of a spark through a conductor having inductance, the discharge, provided the resistance of the circuit is small, will be oscillatory. The circuit (Fig. 2), instead of being traversed by a current in one direction which rises quickly to a

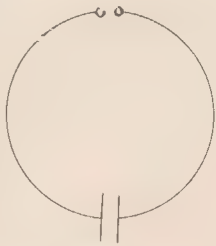

Fig. 2
Closed oscillatory circuit

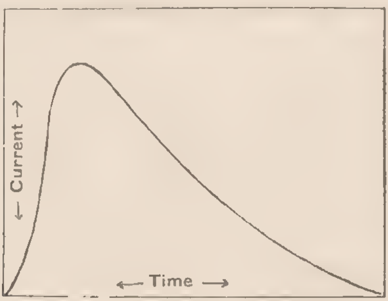

Fig 3

Curve showing dead-beat nature of condenser discharge when circuit contains high resistance

maximum and then dies down more slowly (Fig. 3), as would be the case if considerable resistance

were present in the circuit, will have established in it a current which rises to a maximum, descends to zero, attains a maximum in the reverse direction and repeats the operation till the energy has been completely dissipated in the light and heat of the spark and in heating the conductor. The amplitude of each swing is less than the one preceding it, and bears a constant ratio to it, and if the naperian logarithms of each amplitude are written down it will be seen that they exhibit a constant

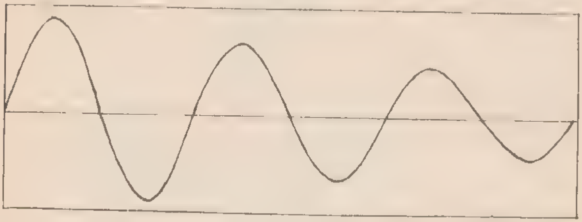

FIG. 4

Showing oscillatory nature of discharge when resistance of circuit is small

difference ; this difference is termed the logarithmic decrement of the oscillation (Fig. 4).

Fig. 5 shows in a modified form a hydraulic model of a Leyden jar or condenser, devised by Sir Oliver Lodge, and serves admirably to illustrate the fact that under certain conditions the discharge is oscillatory. The model consists of two glass jars, representing the two plates of a condenser; the jars are connected on their under side by means of a U-shaped tube provided with a stop-cock, the tube representing the discharger. Now suppose the stop-cock to be closed and one jar to be filled with water, also suppose that the U-shaped tube be partially filled with sand; if now the cock is opened the water will rise in the second jar quickly at first and, as the differ-

ence in level decreases, more slowly, until the water is at the same level in both jars. This illustrates the case of a condenser discharged through a conductor of considerable resistance, the discharge in the electrical case being accompanied by a current in one direction only till the plates of the condenser are both at zero potential and in the case of the hydraulic analogue by a flow of water in one direction only till the water level is the same in both jars. Now suppose the sand-choked tube to be removed and replaced by another of fairly large internal diameter and, the cock being

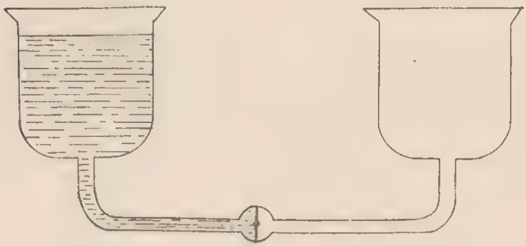

Fig. 5
Hydraulic model of Leyden jar

closed as before, one jar to be again filled with water. On the stop-cock being opened the water in the first jar will rush through the tube into the second jar, but owing to its inertia it will not stop when the pressure in the two jars is equalised but will continue to flow till the water in the second jar is at a higher level than that in the first; it will then flow through the tube in the reverse direction and again will not stop on the water obtaining equal level in the jars, but will continue to flow till the first jar is at a slightly higher level than the second. The operation will then be repeated till by the viscosity of the water and the

friction on the sides of the jars and tube it is finally brought to rest and the water level is the same in both jars. This serves to illustrate the oscillatory character of a condenser discharge through a conductor of low resistance. In the electrical case the discharge is accompanied by a current in the conductor which periodically reverses its direction and by the periodic reversal of the sign of the potential difference at its terminals. In the case of the hydraulic model we have seen that on the stop-cock being opened—which represents the passing of the spark in the electrical case—there was a current of water set up in the tube which periodically reversed its direction of flow, also the difference in water level in the two vessels periodically reversed, which is the analogue of the alternating potential differences of the condenser.

It was further demonstrated that the frequency of the oscillations depended on the electrical dimensions of the circuits—that is to say, upon the value of their capacity and inductance—and can be found from the formulæ $N = \frac{5 \cdot 033 \times 10^6}{\sqrt{CL}}$; where N = Frequency; C = Capacity, and L = Inductance. If the circuit is given a suitable form, as Fig. 6, some portion of the

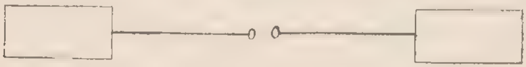

FIG. 6

energy will be radiated and the æther thrown into a state of vibration. These vibrations can be detected at a distance by means of another and similar circuit, provided that the product of its inductance and capacity is numerically equal to that of the propagating circuit. When the product of the capacity and inductance of one circuit is equal to that of another circuit they will oscillate to the same frequency and

are said to be in tune or resonance with each other.

Sir Oliver Lodge has devised an apparatus for the demonstration of resonance effects, the construction of which is as follows. A condenser, usually a Leyden jar, and a conductor having inductance were joined across the spark balls of a Rhumkorff coil (Fig. 7); another circuit (Fig. 8), consisting of a capacity and variable inductance and having a small spark gap shunted across the terminals of the condenser, was set up at a short distance from it. When the Rhumkorff coil was set going minute sparks were observed to jump the gap shunted across the terminals

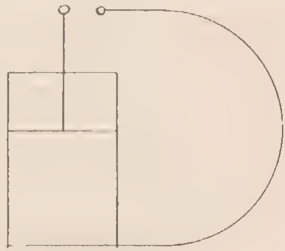

FIG. 7

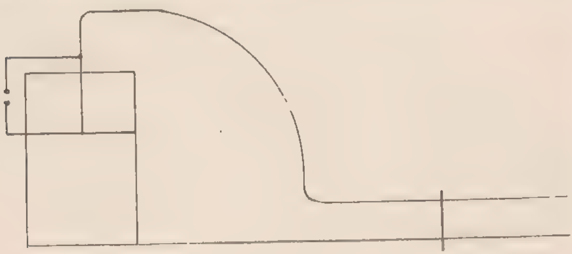

FIG. 8

of the condenser in the detecting circuit, but only when by adjusting its capacity or inductance it had been brought into resonance with the sending circuit. For the purposes of practical Radio-Telegraphy the means

already described for exciting the oscillations and detecting them at a distance are unsuitable, and it was not until Signor Marconi brought out his first apparatus that a system suitable for the transmission of messages came into being. Marconi's first apparatus (Fig. 9) consisted of an induction coil, one side of the spark gap of which was connected to an insulated vertical wire termed an antennæ, the other side being connected to an earth plate; in the primary circuit of the induction coil was a Morse key, by means of which the signalling was effected. It will be noticed that this arrangement is, as Fig. 6, one arm of the Hertzian oscillator, as it is termed, being in a vertical instead of a horizontal position, and the other arm being replaced by the earth.

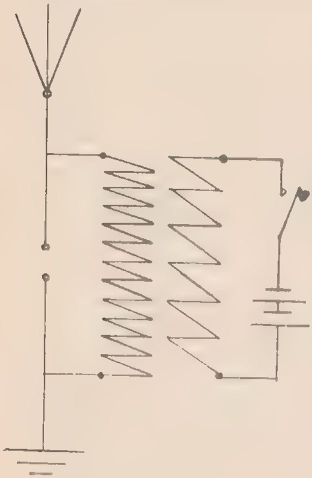

FIG. 9
Arrangement of first Marconi transmitter with plain aerial

The receiving device (Fig. 10) consisted of an improved form of Branly filings tube, one terminal being connected to the aerial and the other to earth. The details of the construction of the tube are shown in Fig. 11. It consists essentially of two metallic plugs fitting tightly into a small glass tube and between which are placed a small quantity of nickel filings. In its normal condition these filings have a very high resistance and constitute practically a break in the

circuit of the relay in which it is included. As soon, however, as electrical impulses are set up in the aerial its resistance drops enormously and it becomes comparatively a good conductor and a current passing through the coils of the relay enables it to actuate a Morse printer, which with a battery of dry cells is joined across its contact terminals. The coherer after the electrical impulses have ceased to act upon it has not of itself the ability to return to its former high resistance; a small electro-magnetic hammer is therefore included in the circuit of the Morse printer, which by tapping gently on the coherer restores to it its former high resistance and again renders it sensitive to electrical impulses.

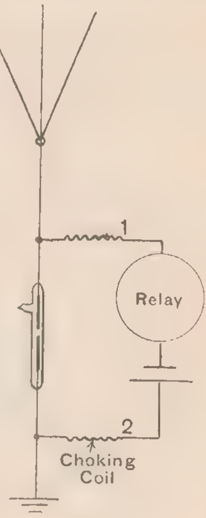

FIG. 10
Arrangement of first Marconi receiver coherer directly in antennæ circuit

The practice of inserting the spark gap directly in the antennæ has—owing to the impossibility of imparting large energy to so small a capa-

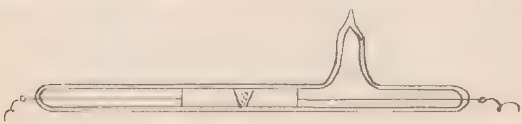

FIG. 11
Marconi coherer

city as a vertical wire possesses with respect to the earth—been abandoned in favour of the inductive

method (Fig. 12), by means of which considerable energy can be imparted to a condenser of large capacity situated in a closed or persistently oscillating circuit and inductively transferred to an open or good radiating circuit which is coupled to it. The coherer also has now almost disappeared, being

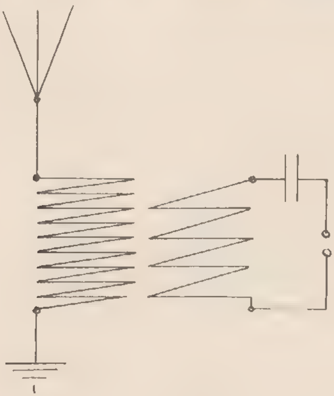

Fig. 12

replaced by one of the newer detectors, either magnetic, thermo-electric or valvular, all of which are used in conjunction with a telephone receiver. These detectors far exceed the coherer in sensitiveness, and require very little adjustment, the result being that communication can be carried on over much greater distances and with greater reliability.

CHAPTER II

THE TRANSMITTER

Closed and Open Oscillatory Circuits—Arrangement of Circuits—Condensers for Transmitting Circuits—Inductances—Spark Gaps—Induction Coils and Transformers—Morse Keys—Motor Generators—Accumulators

Closed and Open Oscillatory Circuits

We have seen in the preceding chapter that the discharge of a condenser in a circuit consisting of capacity and inductance, provided the resistance is small, will be oscillatory and that the amplitude of each oscillation is less than the one preceding it; in other words, the amplitude decays and the oscillations are said to be damped. The damping of the oscillations or loss of energy is due partly to internal losses in the circuit, due to the resistance of the circuit and partly to losses by radiation. Consider now a circuit formed of a capacity and an inductance as Fig. 2, Chapter I. In such a circuit the losses will be due almost entirely to the resistance of the discharger and spark, for the reason that the lines of force are concentrated between the plates of the condenser and consequently there is little external field produced, and therefore but slight radiation, as it is necessary for the production of radiation that the lines of force should extend far out into space. The oscillations in a circuit of this form, which is known as a closed circuit, will, it will be seen, be but feebly damped as there are no losses by radiation. From the foregoing we conclude that a closed

oscillatory circuit is only suitable for the generation of oscillations and cannot be used for their radiation.

Figs. 6 and 9, Chapter I., show a form of open oscillatory circuit or one in which the lines of force extend far out into space. The oscillations in such a circuit will be much more rapidly damped, as in addition to the circuit losses we have those due to the radiation of energy, A circuit of this form therefore is not suitable for the generation of persistent oscillations, but is admirably adapted to their radiation.

Arrangement of Circuits

A vertical earthed wire having a spark gap inserted in its base and excited by an induction coil, although an excellent radiator, has very little capacity, and consequently its energy storage is small, likewise, being a good radiator, the oscillations set up in it are rapidly damped. The ideal arrangement would be one possessing good radiative properties and considerable energy storage, and at the same time a persistent oscillator to enable the benefits of resonance to be made use of. Sir Oliver Lodge's solution of the problem is a compromise between an open or good radiative circuit and a closed circuit which is a persistent oscillator and has large energy storage owing to the large capacity which may be given to it.

Fig. 13 shows the form which his antennæ takes. A and B are capacity areas connected one to each side of the spark gap; included in the leads are variable inductances for tuning; such an arrangement, by increasing the capacity, enables a much larger amount of energy to be put into the antennæ, also, as it is a partially closed circuit, the oscillations in it will be more persistent, although the radiative properties it possesses are less than those of the vertical wire before mentioned.

Other investigators tackled the problem in a

different way by exciting the oscillations in a closed circuit and inductively transferring them to an open or good radiative circuit. The open or antennæ

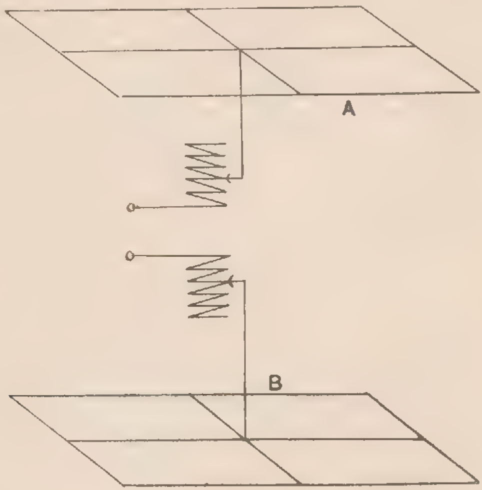

Fig. 13
Lodge Muirhead antennæ

circuit may be coupled to the closed circuit in several different ways. Fig. 14 shows what is known as the direct coupling method, the closed circuit consists of a capacity, usually a number of Leyden jars, joined in series with the spark gap and an inductance. The antennæ and earth are connected to two points on the inductance, as shown in the diagram. The second method is the inductively coupled method. In this case the closed circuit is built up as before, but the antennæ and earth are connected to a second coil, which is placed within the coil of the closed circuit,

and the two are then immersed in oil. Means are provided for the adjustment of the distance between these coils in order that the coupling may be varied. In both the direct and inductive methods it is essential that the antennæ circuit and the closed circuit are tuned to the same frequency, as if this is not the case the energy in the closed circuit will not be transferred to the antennæ.

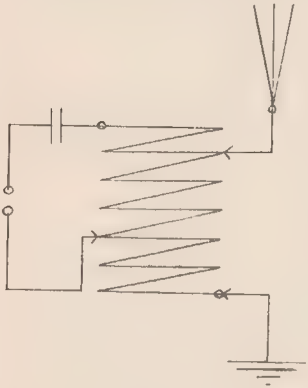

FIG. 14.—Circuits of directly coupled transmitter

With a coupled arrangement as described it will be found that oscillations of two frequencies are emitted; this is due to the reactions of the circuits on one another, and is a disadvantage, as the energy is split up and the receiver can only make use of the energy of the frequency to which it is tuned. If, however, the coupling between the circuits is made very loose the two frequencies tend to approach each other, and at a certain coupling will be so close as to be indistinguishable.

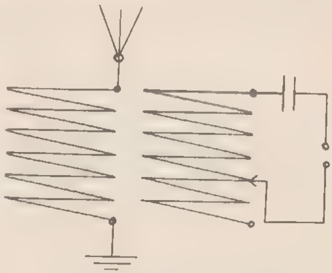

FIG. 15.—Circuits of inductively coupled transmitter

In setting up a transmitter the following points

should be carefully attended to. The spark gap should be free from points or roughness, as these encourage premature discharge; the chamber in which the spark gap is enclosed should be kept thoroughly dry, and care should also be taken that no brushing takes place from the condensers, as this causes useless dissipation of energy. It is sometimes advisable to immerse the condenser in oil, as this effectively prevents brushing. The primary and secondary circuits, as before mentioned, must be exactly tuned; a convenient method of doing this is to insert a hot wire ampère meter in the base of the antennæ and then to adjust the circuits till it shows the largest reading.

Condensers for Transmitting Circuits

In the construction of a condenser for use in the transmitting circuit we have to consider what material used as a dielectric will absorb least energy; also we must so construct it as to withstand the high voltage to which it will be subjected. The losses in a condenser may be classed under two heads: first, those due to the hysterisis of the dielectric and secondly those due to brushing that may take place from the edges and corners of the plates. The hysterisis losses vary considerably with the material of the dielectric and also with the frequency being greater for high frequencies; in respect of internal losses an air condenser would be ideal, as the internal losses when air is the dielectric are nil; we are as a general rule, however, faced with a practical difficulty —namely, the space required for the housing of such a condenser, as owing to the fact that the dielectric strength of air is small the plates would have to be a considerable distance apart to withstand the pressure. In practice, therefore, the types of condenser most frequently met with are those consisting of metal

plates arranged in a glass containing vessel and immersed in oil, and the well-known Leyden jar, the latter being by far the most generally used.

The specific inductive capacity of glass is very high, being about nine times as great as air; this, together with the fact that it has great dielectric strength, enables the condenser to be kept within reasonable dimensions. The jars are built up in groups, sufficient being put in series to safely withstand the tension, and then in parallel till the required capacity is obtained.

If the jars show considerable brushing while in use, an improvement may be effected by putting more jars in series and so lessening the tension across each jar, but if this is done it will of course be necessary to add more in parallel to bring the condenser back to its original capacity. The measurement of the capacity of condensers will be dealt with in the chapter on measurements.

INDUCTANCES

In the chapter on high-frequency resistance we shall see that the resistance of a solid metallic conductor of large section is not the same for currents of high and low frequency, but may be much greater for the former by an amount which depends partly on the frequency and partly on the thickness of the wire; the reason being that high-frequency currents or oscillations confine themselves to the surface of the conductor and penetrate to no appreciable depth; we shall also see how this increase in resistance may be avoided by using conductors built up of a large number of small wires insulated from each other and joined in parallel. In the construction of inductances for use in the sending circuit, however, it is hardly practicable so to construct them, as it is necessary that the induc-

tance should be continuously variable or at least variable in small steps. The usual practice, therefore, is to use tubes or flat strips having large surface which have a similar effect in keeping the difference between the high and low frequency value of the resistance small. The practical shapes taken by the inductances will be seen by reference to the photographs of the various systems. In the Telefunken system they take the form of flat spirals, a form of inductance also used in the Lepel portable installations; in the Poulsen and De Forest systems it will be seen that the inductances consist of copper tubes wound round a cylindrical former, connection being made to various points by means of clips.

Spark Gaps

The spark gap takes various forms; in some systems the spark is taken between blunt rods, in others between balls. Plates and rings are also used, but never sharp points, as these cause premature discharge. The chief point to be considered in a spark gap is its resistance, which should be kept as low as possible.

It has been found that the resistance of a spark gap decreases with its length till a certain point is reached after which it increases with the length of the spark gap, rapidly if the condenser discharging across it is small and less rapidly as the condenser is made larger. The length of the spark to give best results for any given transmitter is best found experimentally. A hot wire ammeter should be included in the antennæ and, assuming that the circuits have already been tuned to each other, the spark length should be varied until the greatest reading is shown on the meter. The resistance of the spark gap, however, varies not only with its length

but with the amount of energy discharged across it. Thus for a given length of spark the larger the energy the less will its resistance be, for this reason the condensers in the circuit are given as large a capacity as possible.

The voltage required to break down the insulation of the spark gap depends not only on the length of the gap but upon the size and shape of the discharger, if the latter consists of balls, the greater the radius of the balls the larger will be the voltage required to break down the insulation of the air gap; as it is very important that there should be no brushing or premature discharge, the balls should be of fair size and kept quite smooth. The spark gap is sometimes placed in a compressed-air chamber, as the voltage required to break down a given spark length is much greater in compressed air than in air at ordinary pressure, consequently the condenser can be charged to a much higher voltage. The noise from the spark is terrific, and it is therefore the practice to enclose it in a muffled chamber, or else to place it in a room by itself away from the operator; the ozone which is given out by the spark is also very objectionable, and means are therefore taken to conduct it to the outer atmosphere.

The Marconi Company has brought forward of recent years a spark gap which consists of two discs rapidly rotated, the spark taking place between their peripheries. This form of spark gap can be used either with direct or alternating current. The advantages claimed are that although a true oscillatory discharge may take place across the gap the rapid relative motion of the discs effectually prevents the formation of an arc. It is also claimed that when used with direct current the oscillations given out are practically continuous and undamped, and for use therefore with spark receivers the periphery of one or both discs are studded, to cut up the oscil-

lations into wave trains of suitable frequency. The spark gaps used in the newer quenched spark method will be found fully described in the section devoted to the Telefunken and Lepel systems.

Induction Coils and Transformers

In small power stations the condenser is charged by an induction coil. This piece of apparatus consists, as is probably well known to most of the readers of this book, of a number of turns of thick wire, termed the primary, wound on an iron core built up of a large number of fine iron wires insulated from each other by varnishing. The object of thus building the core is to prevent eddy currents from being set up in it and the consequent loss of energy. Over the primary is wound a large number of turns of very fine wire which is termed the secondary ; the secondary is not usually wound on in layers extending the whole length of the coil, but in small sections, the object being to prevent high potentials from existing between adjacent turns, which might break down the insulation, the ends of the secondary are connected to the spark gap terminals. In series with the primary is an interrupter of some kind, usually of the hammer type, which is actuated by the magnetism of the core. Across the break of the interrupter is shunted a large capacity, the function of which is to suppress the sparking, and by so doing to render the interruption of the primary current more sudden. As the purpose for which the induction coil is used in Radio-Telegraphy is to charge a condenser, the secondary windings of coils intended for that purpose are wound with a thicker wire than is usually the case. The primary current is supplied usually from a battery of secondary cells, but sometimes the coil is worked directly off the lighting circuit of the ship or station, a regulating

resistance being joined in series with it. In stations intended for long-distance working it is necessary to use much larger energies than an induction coil is capable of dealing with; recourse is therefore had to an alternating current transformer which is supplied with current from an alternating current dynamo, usually single phase. The construction of a transformer for alternating currents is somewhat similar to an induction coil. It consists of a primary winding of few turns and large section wound over a laminated iron core and a secondary of many turns wound over the primary. As the current supplied to it is alternating there is no need for an interrupter. Great care must be taken to secure perfect insulation, and to this end the transformer is usually immersed in oil of high insulating properties.

For the purpose of Radio-Telegraphy it is usual to supply current at from 200 to 500 volts and to transform it up to 40,000 or 50,000; the ratio of transformation being determined by the relative number of turns on the primary and secondary.

In measuring the power in a circuit carrying an alternating current, the product of the volts and amperes as read on separate meters must be multiplied by the power factor, otherwise it will be usually in excess of the true power in the circuit. This is due to the fact that if capacity or inductance is present in the circuit it will tend to throw the volts and ampères out of phase—that is to say, they will not attain their maximum values at the same time. As, however, the power factor is in most cases an unknown quantity, it is better to measure the power by some suitable form of wattmeter, which takes account of the phase difference which may exist and gives the true power in the circuit in watts.

Morse Keys

For small power installations the Morse keys used are not very different from those employed in ordinary

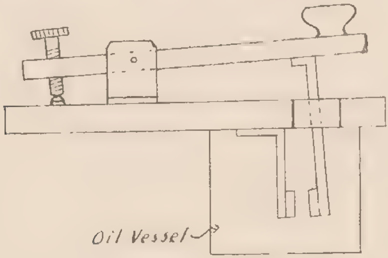

Fig. 16

Morse key. Circuit broken in oil

land line telegraphy, the only difference being that the platinum contacts are larger; when, however, it is desired to interrupt large currents precautions must be taken to eliminate the heavy sparking which occurs when the key is opened. Fig. 16 shows a form of Morse key much used in the larger installations; it will be seen that the contacts of the key are immersed in oil, which when the circuit is broken by the opening of the key flows into the gap and effectually prevents the formation of an arc. For use on an alternating current circuit a key constructed as Fig. 17 is sometimes

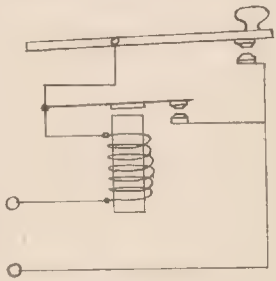

Fig. 17

Minimum current break

used. It is known as a minimum break key, and its action is as follows. When the operator depresses the key and closes the circuit, the current flows through the winding of the electro-magnet A, which forms part of it; the magnet on being thus excited attracts its armature and closes the contacts placed in shunt to the main key contacts; if now the key is opened the auxiliary contacts will not immediately follow, but will remain closed until the alternating current during its cycle of changes is approximately zero. It will thus be seen that there is no danger of an arc forming, as the circuit is not opened until the current is practically nil. In some installations the sparking at the contacts is avoided by shunting the key with a large capacity or with a non-inductive high resistance.

Motor Generators

The power, except for very small stations using induction coils which can be worked from accumulators or directly off the lighting circuit of the ship, is supplied by an alternating current dynamo coupled on the same shaft as a direct current motor built to run off the ship's supply. The motor, which is of the shunt type, is provided with a starting switch and a rheostat is included in the shunt circuit for regulating the speed of the motor. The starting switch (Fig. 18) performs the following operations and in the order named. When moved from its position of rest it first makes contact with a segment which completes the circuit through the field coils, which are then fully excited, it next closes the circuit through the armature of the motor, the starting resistances being in series with it. As the motor gathers speed the switch arm is moved further round, and the resistance diminished step by step until, when the motor has attained its maximum speed, they are finally cut out altogether.

In starting the motor, the switch should only be kept on each segment long enough for the motor to attain its top speed for that segment and then moved on to the next. If this is not done, and the arm is

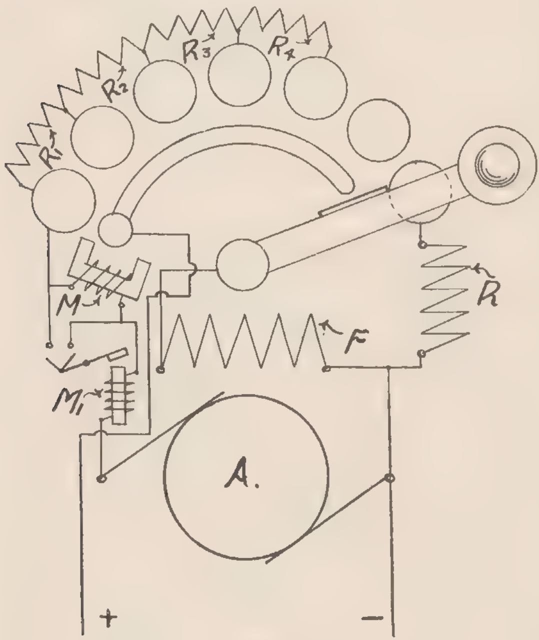

FIG. 18

Motor starting switch

kept too long on one segment, it may result in the heating up of the starting resistances. Referring to the diagram, *M* is an electro-magnet whose coil is included in the main circuit, the function of this magnet is to hold over the arm of the switch while the

motor is running, and if from any cause the supply current is cut off from the mains the arm will be released, and by the action of a spring will be carried to the off position. The motor will thus be protected from the damage that would occur if it had come to rest and the supply current was switched right on the armature without the starting resistance being in series with it. M_1 is also an electro-magnet whose coil is included in the main circuit. The function of this coil, which is termed an overload release, is to automatically cut off the supply current should it from any cause rise to dangerous proportions; it does this in the following way. The coil is furnished with an armature so arranged that the normal current flowing through the coil is insufficient to attract it, but if the current is increased beyond a certain value the armature will be pulled down and when in this position will short-circuit the coil of the magnet M, and the switch arm being thus released will move over to the off position.

Referring again to the diagram, F is the field magnet coil, A the armature of the motor, R_1 R_2 R_3 and R_4 the starting resistances, and R is a resistance about equal to the field-magnet coils. It will be seen that when the motor is stopped the arm of the switch in moving back to its position of rest will put this resistance in parallel with the field coils before their circuit is broken, the function of the resistance being to take up the current induced by the opening of such a highly inductive circuit as the field magnets; if this precaution were not taken it is probable that the insulation of the field magnet coils would be damaged. The alternating current dynamo, which is coupled on the same shaft as the motor, is of the single phase type and is usually built to give a voltage of from 200 to 500 volts. The frequencies most commonly used range between 50 and 150 cycles per second. For a given speed the frequency will depend on the

number of pairs of poles; thus, supposing the armature makes 2400 revolutions per minute, and there are one pair of poles, the number of cycles would be 40 per second; if the machine had two pairs of poles the number of cycles would be 80, and if it had three pairs the number of cycles would be 120 per second.

The field magnets of the alternator are excited by current from the direct supply which drives the motor, and a rheostat is included in their circuit to enable the voltage to be adjusted.

ACCUMULATORS

Accumulators, or secondary cells, are of two types—the pasted type and the formed type. In the case of the pasted type the plates are prepared by pressing oxide of lead into a leaden grid so formed that the paste shall make intimate contact with it and be firmly held in position. The plates are immersed in dilute sulphuric acid and held apart by glass rods or by corrugated celluloid separators. If now they are connected to the poles of a direct current dynamo or other source of direct current, electrolytic action takes place which still further oxidises one of the plates, whilst on the other plate the oxide is reduced and the lead rendered spongy or porous; the spongy plate is termed the negative plate, the other plate being the positive. In the formed type of cell the active material is produced by electro-chemical means. An accumulator cell when fully charged has a voltage of about 2·3 volts. To charge such a cell or group of cells the following procedure should be adopted.

The positive plate of the accumulator should be connected to the positive pole of the charging dynamo and the negative plate to the negative pole of the dynamo; included in the circuit should be a variable resistance to regulate the charging current, which

should not exceed 20 per cent. of the capacity of the cell; thus, supposing the cell to have a capacity of 50 ampère hours, the charging current should not exceed 10 ampères, and preferably should be less. During charging the vent pegs should be removed. The safe discharging rate is about 25 per cent. of the capacity, and the voltage per cell should never be allowed to fall lower than 1·85 volts.

These cells have a very low internal resistance and their efficiency is about 80 per cent.

The faults most likely to occur are the following:—Buckling of the plates, due in most cases to excessive rate of discharging; the same cause is also frequently responsible for the disintegration of the plates which sometimes occurs. Another fault to be guarded against is the sulphating of the plates, an insoluble substance termed sulphate of lead forming on the plates, the cause may be any of the following:—too strong a solution of acid, discharging the cell too low, under-charging or leaving the cell partially discharged for long periods without removing the acid. The remedy is to give the cells a prolonged charging at a low charging rate. The acid solution is made up of 9 parts water and 1 part commercial sulphuric acid, the specific gravity of the acid solution being about 1·2.

Most makers of storage batteries send out full instructions with them, as to charging and discharging rates and general treatment, and it will conduce to the long life and satisfactory working of the cells if these instructions are faithfully followed.

CHAPTER III

THE ANTENNÆ

Practical Forms—Earth Connection

Practical Forms

The antennæ is that portion of a Radio-Telegraph installation which radiates or absorbs energy. It consists in its simplest form of a single vertical wire, but the modern practice is to have a number of wires in parallel. This has the effect of increasing the capacity, and therefore the amount of energy that can be put into it. It also diminishes the resistance of the antennæ and thereby reduces the damping. The wires should not be too close together, but well spaced, if the full benefit in increase of capacity is to be obtained; this is owing to the fact that if they are close together the distribution of the lines of force is unsymmetrical for each wire. The best material for an antennæ is copper or bronze wire, preferably

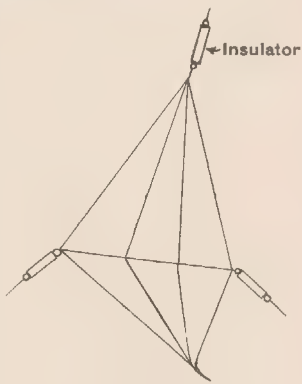

Fig. 19
Inverted fan antennæ

stranded, 7/20 is a very convenient size. The form the antennæ will take depends upon circumstances

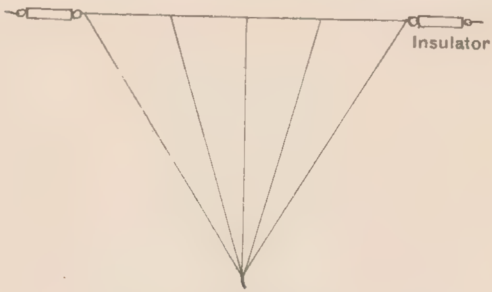

Fig. 20
Fan antennæ

—such as amount of ground available, number of masts, etc.

Fig. 19 shows a very convenient type: it consists

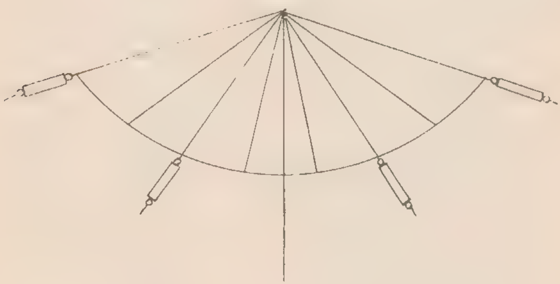

Fig. 21
Umbrella antennæ

of four wires connected together at the masthead and spread out by means of a rope like an inverted fan. The wires are then bunched together at their lower

ends and led into the station. If two masts are available an excellent antennæ can be constructed as in Fig. 20, the vertical wires being connected to a horizontal one at their upper ends. A favourite type of antennæ is that shown in Fig. 21 and known as an umbrella antennæ. It consists of a vertical portion from the top of which radiate a number of wires like the spokes of a wheel; these wires should be connected at their lower ends to another wire which encircles the mast; the horizontal wires, while they do not increase the radiation, add largely to the

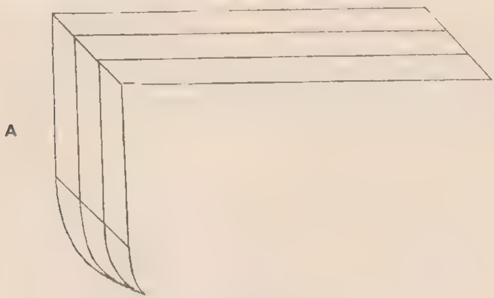

Fig. 22
Marconi directive antennæ

capacity of the antennæ. An antennæ constructed as that shown in Fig. 22, which is the type used by the Marconi Company at their Transatlantic station at Clifden, will have the effect of concentrating the radiation mainly in one direction, for the reason that the lines of force stretch farther out into space in the direction of A, which will be the direction of maximum radiation; in directions approximately at right angles to this the radiation will be a minimum.

As regards antennæ for ships there is not much choice as to shape, and they usually consist of a number

of wires stretched horizontally between the masts, the perpendicular portion being connected about the middle, as shown in Fig. 23. Great care should be taken to secure proper insulation of the antennæ, particularly at the masthead, as it is there that the potential is greatest. A very convenient and efficient form of insulator is shown in Fig. 24. It is made of porcelain, is an excellent insulator and has good mechanical strength: the

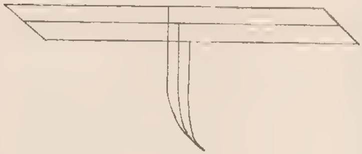

Fig. 23
Ship's antennæ

Fig. 24

type of insulator used to bring the antennæ into the cabin is shown in Fig. 25. Care should also be taken in the construction of an antennæ to

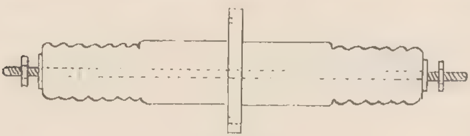

Fig. 25
Antennæ leading in insulator

keep it free from points and sharp edges, as brushing is likely to take place from these. To sum up, the qualities it is desirable that the antennæ

should possess are: good radiative properties; low resistance to high-frequency currents; a fair amount of capacity to enable it to store energy; and good insulation, which in the case of conductors carrying high-frequency currents means that not only should they be well insulated for conduction currents, but that they should be kept away from all earthed metal-work, as if they are near to it, and especially if they run parallel to it for any distance, a dielectric current passes.

Earth Connection

Great difference of opinion exists as to the advisability of earthing the antennæ, Sir Oliver Lodge maintaining that the earthing of an antennæ is inimical to very sharp tuning. The general opinion, however, is that the antennæ should be earthed, and that if the system of earth wires is properly constructed it is beneficial and increases the distance over which signalling can be carried on. In the early days of Radio-Telegraphy it was a common practice to use a copper plate buried in the ground as an earth, but by experiment it was found that the best earth connection was formed of a large number of wires laid in the ground radially from the station and stretching out from it as far as possible. It is not necessary that the wire should be deeply buried, if the station stands on grass-land it is sufficient to turn up the turf, insert the wires and replace it. At the point where the wires meet they are connected together and led into the station. Fessenden in America devised what he called a wave chute, which consists of an arrangement of wires identical with that above described, the wires, however, being laid on the surface of the ground and not buried. In a ship station the earthing is effected by connecting to the side of the vessel.

CHAPTER IV

THE RECEIVER

Arrangement of Receiving Circuits—Detectors—Telephone Receivers—Blocking Switches

Arrangement of Receiving Circuits

The practice of inserting the detecting device directly in the antennæ has been universally abandoned, and the detector is now placed in a circuit which is either directly or inductively coupled to the antennæ. The arrangement of the circuits when direct coupling is used is shown diagrammatically in Fig. 26. It consists of a long spiral of insulated copper wire wound on an ebonite tube, the insulation of the wire being removed for a small space on each turn to admit of a slider making metallic contact. One end of the coil is connected to the antennæ and the earth wire is connected to the sliding contact, the detector being shunted across two points of the coil. As will be seen, the tuning is effected by varying the inductance of the antennæ circuit. Such an arrangement has the merit of extreme simplicity inasmuch as there is only one variable, and the movement of the slider from top to bottom will, if the coil is a fair size, cover a large range of wave lengths. In actual use, however, it has been found that the sliding contact is apt to become dirty and make indifferent contact with the coil which by introducing resistance increases the damping and thereby weakens the signals. When using such a tuner it is not possible to get very fine

tuning, but as a call-seeking device, or where by reason of inability to secure highly skilled operators extreme simplicity is necessary, it has its advantages. The method of inductive coupling is the one most generally used, the tuners usually consist of three circuits, a primary or antennæ circuit, a secondary circuit which is tuned to the primary and coupled to it and a tertiary circuit which is untuned and contains the detector.

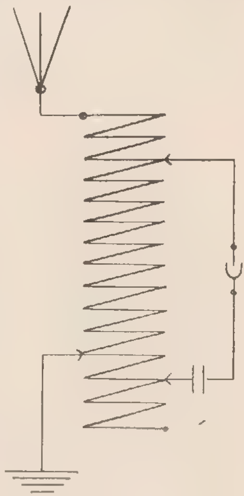

Fig. 26

The coils for such a tuner should preferably be laminated—that is to say, instead of using a solid copper wire it should be built up of a large number of very small insulated wires laid side by side. The reason for this is that, when a conductor is traversed by high-frequency currents, the current tends to confine itself to the surface, and penetrates to no appreciable depth; the resistance of the wire is therefore many times higher for currents of high frequency than for steady currents. As, however, a conductor built up of many insulated strands has a very large surface, the difference between its resistance to high-frequency currents and its resistance for steady currents will not be great, as would be the case with a solid conductor, whose surface is small compared with its cross-section. It is also advisable that the coils should not be too closely wound, as close winding tends to confine a high-frequency current to a certain part of the surface

of the wire, and this also it will be seen would still further increase the resistance. Fig. 27 shows diagrammatically the arrangement of an inductively coupled tuner. A is the primary coil whose terminals are connected to antennae and earth respectively; across the coil is shunted a variable condenser by means of which the tuning is effected. B is the secondary circuit. It consists of a coil of wire and a variable capacity for tuning the circuit to the primary. (In the diagram the coil is shown as con-

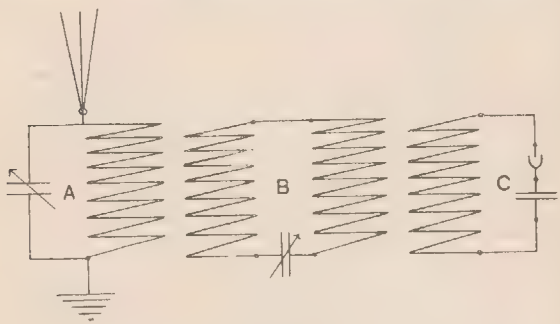

FIG. 27
Circuits of three-coil inductively coupled receiver

sisting of two parts, this need not be, and in fact usually is not the case, but is so shown simply to make the diagram clearer.) C is the tertiary circuit and consists of the coil, fixed capacity and the detector. The function of the condenser in this circuit is to act as a shunt to the telephone, which by reason of its high self-induction would act as a choking coil and prevent oscillations from being set up in the circuit. It usually consists of a small mica condenser having capacity of about 5000 centimetres. This circuit is untuned and in fact the presence of the detector renders

tuning impossible. The action of the tuner is as follows. On the primary circuit being tuned to the transmitter from which it is desired to receive signals, oscillations are set up in it and the primary, acting inductively on the secondary, which is loosely coupled to it, passes the oscillations on, the secondary circuit in turn acting inductively on the detector circuit. It will be seen that owing to the looseness of the coupling no considerable effect can be produced in the secondary circuit unless it is exactly in tune with the primary, and any oscillations of different period that may exist in the antennæ circuit will not be passed on to the secondary and so are prevented from actuating the detector. The rejection of signals not absolutely in tune is one of the chief advantages of the inductive coupling tuner, as considerable interference from neighbouring stations working on only slightly different wave lengths is avoided. In actual practice the tuners take various shapes, in some the coils are mounted on a rod on which they can slide and the coupling varied by bringing them nearer or farther apart. In others the coils take the form of flat

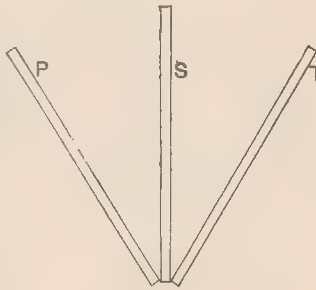

Fig 28

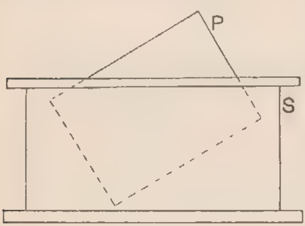

Fig. 29

spirals mounted on sheets of ebonite which are hinged together like the leaves of a book and the coupling varied by opening or closing the leaves (Fig. 28). In the most practical form the tuner consists of two coils placed one within the other, the inner one being so arranged that its plane can be turned through an angle of 90 degrees and the coupling thus varied. The tertiary in this case is not a separate coil, but is formed by tapping off a few turns of the secondary (Fig. 29). The special arrangement of circuits used with the Marconi coherer set will be found in the article on the Marconi System, Chapter V.

Detectors

The detectors used in Radio-Telegraphy may be broadly divided into two classes: those that are potential actuated and those that are current actuated: the former are always joined across the terminals of the condenser, as the potential differences are largest there, and the latter or current-actuated variety are connected in series with the condenser. Detectors may also be further subdivided into classes—namely, imperfect contact devices, such as the Marconi coherer; rectifying devices, such as the Fleming valve and the carborundum detector; electrolytic detectors, as those of Fessenden and Schlomilch; the thermo-electric type, formed of galena against graphite, and various other combinations, and those that depend for their action on the alteration of their magnetic properties.

The Coherer

The coherer, which is the result of the work of many men—Hughes, Lodge, Branly and Popoff among others—consists essentially of a small quantity of

metal filings lying loosely between metallic electrodes. The first practical form of the device for telegraphic purposes was brought out by Marconi, and consisted of a very small quantity of nickel filings, to which were added a small percentage of silver filings, lying between silver electrodes having bevelled ends so that the space between them, in which were the filings, was wedge-shaped.

The purpose of thus bevelling the plugs is to enable the sensitivenses of the coherer to be adjusted. The most sensitive position is when the nose of the wedge is pointing downward and the reverse position is that of least sensitiveness.

The plugs and filings were enclosed in a glass tube,

Fig. 30
Marconi coherer

which was exhausted to a partial vacuum, and the wires connected to the plugs passed out through the ends of the tube (Fig. 30).

The coherer depends for its action on the fact that, if its terminals are subjected to a potential difference above a certain value, the resistance due to the loose contact between the filings and plugs suddenly falls to a much lower value; some investigators think that ordinary electrostatic attraction is a sufficient explanation of its behaviour, others hold that microscopic sparks pass between the filings and slightly weld them together; however this may be, the fact remains that, after being subjected to the potential differences set up by the oscillations, the resistance falls enormously, and if the coherer is joined up with a relay

and cell, and the relay contracts joined up with a Morse writer and battery, the passage of electrical oscillations will be made evident by the closing of the relay circuit and consequent recording of signals. As, however, the coherer will not of itself resume its former high resistance a small electromagnetic hammer is provided to tap gently on its under side, and by shaking the filings loose it restores the coherer to its high resistance and again renders it sensitive to oscillations.

Lodge Muirhead Coherer

This coherer, which is very sensitive and may be used either with a telephone or with a syphon recorder, is constructed as follows:—a small metallic cup (A Fig. 31) contains a globule of mercury on which is placed a small drop of oil, which forms an infinitely thin insulating film over it; above the globule of mercury is a small iron disc with a sharp edge and which is slowly rotated. By means of an adjusting screw the lower edge of the disc is made to touch the oil-covered mercury, but the pressure is not so great as to puncture the film of oil. In series with the coherer is joined a dry cell and telephone receiver, or syphon recorder, as the case may be, and the passage of electrical oscillations, by breaking down the insulating film of oil, allows the cell to operate the receiving instru-

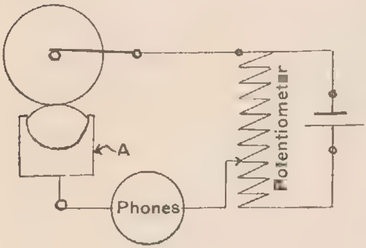

FIG. 31
Lodge Muirhead coherer

ment. This form of coherer is self-restoring and needs no tapping arrangement.

Carborundum Detector

The carborundum detector is very simple in construction, and may consist simply of a small carborundum crystal held between two brass springs. It works by virtue of the fact that carborundum has what is termed an unilateral conductivity. Supposing a crystal of carborundum be joined in series with a battery and galvanometer, and the current noted, and the poles of the battery reversed and the current again noted, it will be found that the two currents differ greatly although the electric-motive force of the battery has remained unaltered. This shows that for currents in one direction carborundum has a very high resistance and is practically an insulator, but for currents in the reverse direction it is comparatively a good conductor. It will thus be seen that a crystal of carborundum can act as a rectifier and change an oscillatory or alternating current into a direct current. Many crystals beside carborundum possess an unilateral conductivity, but not in such a marked degree.

It has also been found that for certain voltages the unilateral conductivity of the crystal is greater than for others, and in practice therefore it is usual to tap the crystal across two points of a potentiometer to the terminals of which a battery is joined. The detector is fairly sensitive and reliable, and is greatly used in the United States.

Fleming Valve

The Fleming valve detector consists of a carbon or tungsten filament lamp, in the bulb of which is also

included a metal plate insulated from the filament, and the connecting wire of which is brought through the glass wall of the bulb to a third terminal outside. If the filament be rendered incandescent by the application of a suitable battery to its terminals the space between the filament and the insulated plate will be found to possess an unilateral conductivity, and if it be now included in a circuit in which oscillations are taking place it will by its rectifying action convert them into an unidirectional current capable of actuating a telephone receiver. The valve is shown in Fig. 32, which also shows the method of connecting it to the circuit.

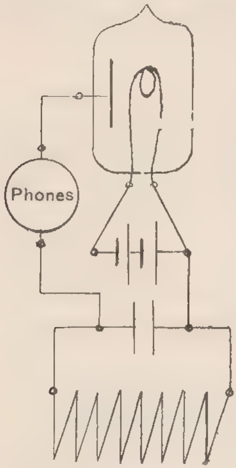

FIG. 32
Fleming valve detector

Electrolytic Detector

This detector consists of a platinum cup containing a solution of dilute acid. The cup forms one electrode and the other consists of a wollaston wire sealed into a glass tube, which is drawn out very fine and then broken off, leaving only the cross-section of the wollaston wire exposed. Connection is made to the wire by means of the metal tube in which the electrode is mounted. The detector with high-resistance phones in series with it is tapped across two points of a potentiometer which has a battery across its terminals. The small current which passes through the detector polarises it—that is to say, gas is formed at

the electrodes and the resistance thereby materially increased. If now the arrangement be subjected to the small alternations of potential and current set up in a receiving circuit by the impact of electrical oscillations it will be depolarised, and the resistance of the electrolytic cell falling, a small current will pass through the phones and will be audible to the operator; after the arrival of each wave train the battery again polarises the cell, the device being thus self-restoring. To adjust the cell, the small electrode having been inserted in the holder and its point dipping into the

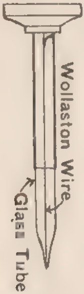

FIG. 33

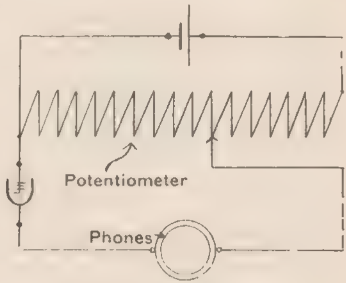

FIG. 34
Electrolytic detector

electrolyte, the arm of the potentiometer is moved round till a hissing noise is heard in the phones, it is then moved back until the noise just ceases. The detector is then in its most sensitive condition. This form of detector is in extensive use, and is very sensitive and reliable; it has been found, however, that atmospheric disturbances, if at all strong, render the device insensitive, but not permanently so, as it restores itself in the course of a few seconds. The restoration may be accelerated by momentarily increasing the voltage across its terminals by moving

the arm of the potentiometer round a little. Fig. 33 shows the wollaston wire electrode and Fig. 34 the method of connecting the detector with battery and potentiometer.

Thermo-Electric Detectors

There are many substances which, when placed in contact and the junction heated, will be found to have a small potential difference across them. The most satisfactory combination for wireless purposes yet found is a small graphite point in light contact with a piece of galena; such a combination is very sensitive and reliable. The practical construction is as follows. A small piece of galena having a good polished surface is soldered into a brass block slightly cupped out to receive it; the block is then fitted to a pedestal on which it is free to move up or down. The graphite, which may be any fairly hard pencil, is fitted into a small split tube mounted on a springy strip and is thus held in contact with the galena. A small screw is provided for adjusting the pressure. Being a current-actuated device, the thermo junction is connected in series with the condenser, and on the passing of oscillations it is heated and a small potential difference thereby is created at its terminals and charges the condenser which discharges through the telephone receiver.

With a good galena crystal the detector requires very little attention, but the passage of strong atmospherics sometimes throw it out of order, due no doubt to its behaving like a coherer and the surfaces of the electrodes becoming slightly welded together. If the graphite and galena are just pulled apart and then allowed to come together again it will be found that its sensitiveness is fully restored.

Magnetic Detector

The Marconi magnetic detector consists of an endless band built up of very fine insulated iron wires. The band passes over two grooved pulleys, which are slowly rotated by means of a clockwork motor, and at a certain point in its journey passes through a small glass tube on which is wound a layer of fine insulated copper wire, the ends of the wire being brought out to terminals. Over this winding is another consisting of many turns of fine insulated wire, the ends of which are also taken to terminals to which the telephone

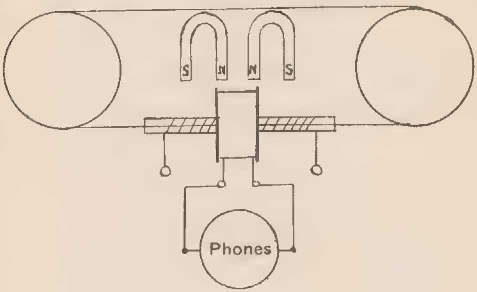

FIG. 35
Marconi magnetic detector

is connected. Above the coils are arranged two permanent horseshoe magnets, the like poles being together as shown in the diagram. The action of the detector is as follows :—The endless iron wire band as it travels past the horseshoe magnets is carried through a cycle of magnetisation, and if now electric oscillations are sent through the primary winding on the glass tube the hysteresis of the iron will be annulled and, owing to the redistribution of the lines

of force which cut the secondary winding, a sound will be heard in the phones. Meaning of hysteresis: When iron is taken through a cycle of magnetisation, it does not at once assume the full magnetic strength; the effect lagging behind the cause, and it is this lagging that the oscillations annul, thus causing the iron band to increase its magnetism. In practical use this detector has proved itself to be sensitive and extremely reliable, little adjustment being required, and beyond occasional winding of the clockwork motor needs no attention.

Telephone Receivers

The telephone receivers used for the reception of wireless messages are not essentially different from those in ordinary commercial use; they, however, differ somewhat in the minor details of construction. As is well known, the telephone receiver consists essentially of a permanent magnet of the horseshoe

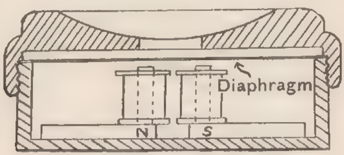

Fig. 36
Telephone receiver

type, having at its poles soft-iron extensions on which are wound a quantity of insulated copper wire, the two coils being joined in series and the free ends brought out to terminals; immediately in front of the pole pieces, and close to them, is a flexible soft-iron disc or diaphragm clamped firmly about its periphery. Fig. 36 shows clearly the construction. Two such

receivers are joined in series and attached to a leather-covered metal band, which passes over the head of the operator so that the telephones fit over the ears. As the telephones are usually in circuit with a high, resistance detector, and the effect depends on the ampère turns, it is customary to wind them to a much higher resistance than the ordinary commercial type. the resistance being from 500 to 5000 ohms according to the nature of the circuit on which they are to be used. As it would be impossible to get the requisite number of turns into the small space of the bobbin, if ordinary silk or cotton insulated wire were used, the bobbins are wound with an enamel insulated wire which occupies much less space.

The telephone receiver is acknowledged to be one of the most sensitive appliances for detecting the presence of an electric current ever invented, its sensitiveness can be judged from the fact that an intermittent current of only a few microamps produces an easily audible sound in it. The loudness of the sound, however, depends not only on the value of the current but on its frequency; it has been ascertained that the telephone receiver has a maximum sensitiveness to frequencies lying between 600 and 1000 per second. This is no doubt due to the fact that the natural frequency of the diaphram is something of this order and also perhaps to the fact that the human ear is affected more strongly by these frequencies.

Blocking Switches

When the transmitter is in use it is necessary that the detector should be protected from the effects of the heavy currents set up in the receiving circuits by reason of their proximity to the transmitter. There are a number of methods of doing this. In the case of the Marconi coherer set a long arm switch is arranged

at the side of the Morse key, which when down or in the send position, completes the power circuit by connecting to contacts which otherwise form a break in the circuit and at the same time by means of a cord passing over a pulley fixed in the ceiling above it lifts the antennæ rod from its socket and so isolates the coherer. It will thus be seen that the connection of the antennæ to the receiver necessitates the opening of the power circuit, and should the Morse key be accidentally depressed the coherer will be uninjured, as no current is supplied to the transmitter; also it will be seen that before the transmitter can be brought into use the arm of the switch must be lowered to short the break in the power circuit and that this cannot be done without at the same time disconnecting the antennæ from the receiver.

In other systems protection is afforded to the detector either by providing it with a low-resistance non-inductive shunt or else by breaking the circuit in which it is situated. The usual method of doing this is by means of auxiliary contacts on the switch used to charge the antennæ from the transmitter to the receiver so arranged that when the antennæ switch is over to send the detector is either short-circuited or its circuit broken, and when it is in the receive position the short circuit removed or the circuit completed while the power circuit is broken. The method of breaking the detector circuit is the more usual and also the more satisfactory of the two, as it is difficult to provide an efficient shunt for the detector owing to the practical impossibility of getting the antennæ switch near enough to the detector to avoid the use of long wires.

CHAPTER V

SYSTEMS OF RADIO-TELEGRAPHY

Marconi—United Wireless—Poulsen—Lepol—Telefunken

MARCONI SYSTEM

ON the smaller Marconi stations it is usual to employ a ten-inch spark coil supplied with current from a battery of secondary cells. The spark is taken between small metal balls and across the spark gap is the primary of the oscillation transformer and the condenser, this latter being composed of a battery of Leyden jars. Inductively coupled to the primary is the secondary winding, one end of which is connected to a variable inductance, and thence to the antennæ, and the other end earthed. In the larger stations the induction coil is replaced by a transformer supplied with current from an alternating current dynamo, but in addition it is usual to provide such a station with an induction coil and battery as well, to render it independent of the ship's machinery, which in the case of an accident might be put out of order. The utility of thus providing an independent set has been demonstrated on several occasions, when but for such provision the probability is that many lives would have been lost.

Fig. 38 shows the arrangement of the receiver. The antennæ, or primary circuit, consists of a variable inductance (by means of which the tuning is effected), the antennæ and the primary of the oscillation transformer joined in series and then connected to earth.

The secondary winding of the oscillation transformer is cut in the middle, but its continuity for electrical

Photo FIG. 37 *Topical*

Marconi installation on the s.s. *Franconia*

oscillations is preserved by the insertion of a condenser.

To the ends of the secondary winding is connected

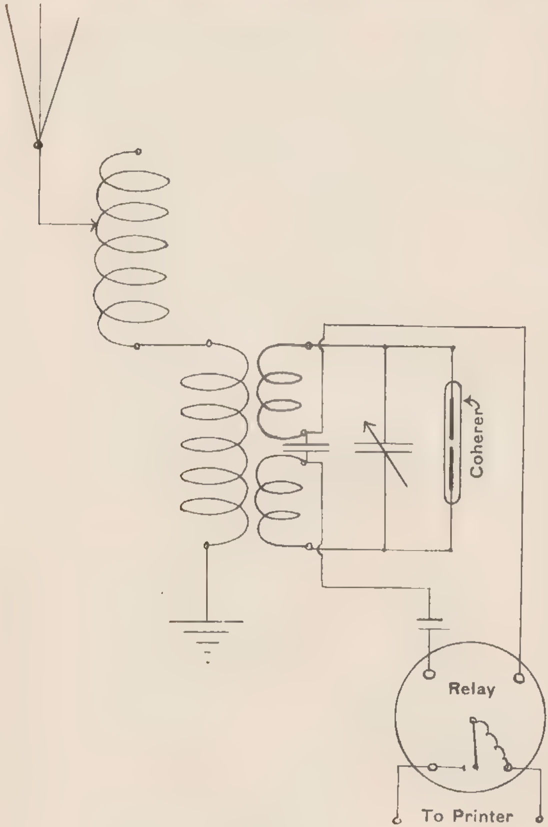

FIG. 38
Circuits of Marconi coherer set

a variable condenser for tuning it to the primary, and

across this latter is the coherer. The relay with a single dry cell in series is connected across the condenser inserted in the break of the secondary winding. To the contact terminals of the relay are joined a battery of cells in series with the Morse printer, and in parallel with the printer is the tapper, the function of which is to shake loose the filings in the coherer after it has been actuated by the oscillations. Owing to the high self-induction of the relay, printer and tapper coils, it is essential that the contacts of these be shunted with non-inductive resistances to eliminate the sparking which would otherwise occur and which though small would be sufficient to actuate the coherer. The adjustment of the various circuits and pieces of apparatus comprised in the above-described set is usually thought to be a difficult matter, but if it is systematically done it will be found fairly simple. The operator should proceed as follows :—first by means of the adjusting screw set the magnet of the tapper as far away from its armature as is possible, then adjust the knob of the tapper so that it is at the distance of about one millimetre from the coherer. The next step is to turn the adjusting screw of the relay till the local circuit closes and then to slowly turn it in the reverse direction till it just opens. Test letters should now be sent on the buzzer (the buzzer is a small trembler movement worked by a dry cell and constitutes a generator of feeble electrical oscillations), and at the same time the magnet of the tapper made to gradually approach its armature till the strength of the beat is sufficient to give good sharp signals on the Morse printer.

If the beat is too weak the signals will tend to run together, and if it is too strong they will be cut up —that is to say, the dashes will appear as a series of dots. The whole of the apparatus above described, with the exception of the printer, is enclosed in a metallic box to prevent damage to the coherer from

the powerful oscillations that would be set up in the circuits when the transmitter was in use. In addition to the coherer set Marconi stations are also supplied with a magnetic detector (described in the chapter on detectors) and it is with this instrument that the greater part of the work is carried on : by its use the distance over which communication can be carried on is vastly increased, it needs little adjustment, and the speed of working is much greater. The type of

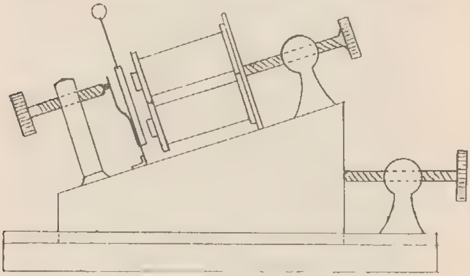

Fig. 39
Marconi decoherer

tuner used in conjunction with the magnetic detector is similar in construction to the three circuit tuners described in the section on receiving circuits, the Marconi Company, however, enclose the whole thing in a case, a lengthening coil is provided for insertion in the antennæ circuit if required and by means of a switch the primary variable condenser can be disconnected from across the primary and put in series with the antennæ if it is desired to receive shorter wave lengths.

Photo Topical

FIG. 40
Marconi field set packed for transport

Photo *Topical*

FIG. 41

Marconi field set ready for use

Marconi Portable Military Set

The photographs Figs. 40, 41 and 42 show a Marconi

Photo Fig. 42 *Topical*

Marconi field set in use

military set. In Fig. 40 the apparatus is seen packed

for transport, Fig. 41 shows the station ready for use, and Fig. 42 the station in use. It will be seen that the complete installation, including mast engine and dynamo, is carried on four saddles. The connections between the dynamo and transformer are made by means of a flexible cable and plugs, and the earth connection by means of the strip of wire-netting spread out on the ground, as shown in Fig. 42. The time required for the erection of one of these stations is very small, about twenty minutes being sufficient.

United Wireless System

The United Wireless Company of New York are

Fig. 43

United Wireless Company's installation at Seward, Alaska

the owners of several important groups of American patents. The photograph, Fig. 43, shows a typical

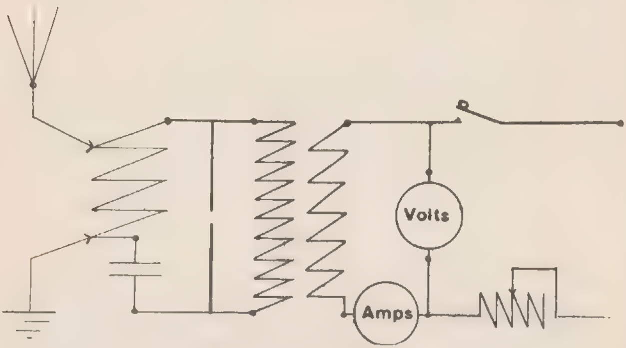

FIG. 44
Circuits of transmitter

station as installed by that company. The power

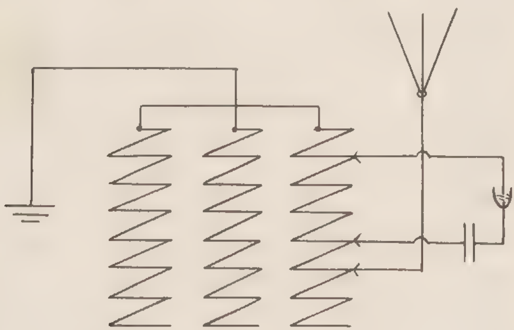

FIG. 45
Three-coil tuning device

supply circuit is made up of the Morse key, reactance

regulator, and primary of alternating current transformer in series, the volt and ampère meters being included in the circuit in the usual way. The secondary of the transformer is joined across the spark gap, which consists of two blunt rods. The primary oscillatory circuit, consisting of a battery of Leyden jars and a number of turns of inductance, is shunted across the spark gap. The direct coupling method is adopted and the antennæ and earth are connected to the inductance by means of clips; the connections are diagrammatically shown in Fig. 44.

The receiving arrangement consists of three variable inductances placed side by side and can be used in a variety of ways. Fig. 45 shows diagrammatically the usual method, the antennæ being connected to the sliding contact of one of the coils, one end of the coils being earthed. If it is desired to receive signals of greater wave length the three coils can be joined in series, and if it is required to receive shorter wave lengths the variable condenser which is mounted in

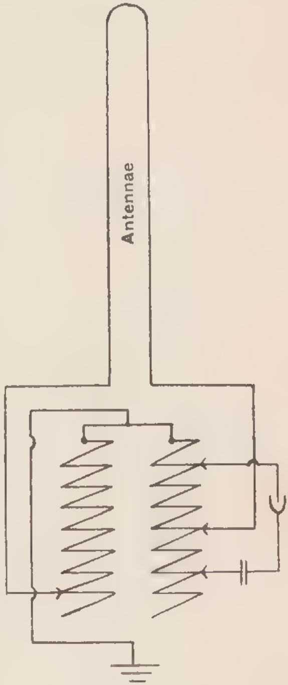

FIG. 46

Arrangement of receiver with looped antennæ

the same case with the coils can be put in series with the antennæ. The detector used is of the crystal variety, and together with the blocking condenser is tapped across two points on the inductance. The antennæ of a united wireless station is sometimes built in the form of a loop. Fig. 46 shows the arrangement of the circuits when this is the case; it will be seen that the antennæ and the inductances form a closed oscillatory circuit and therefore the losses due to radiation are reduced to a minimum.

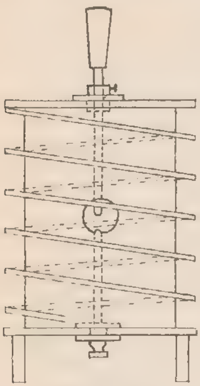

FIG. 47
The spark gap

Referring to Fig. 43, the alternating current transformer is seen on the floor of the cabin to the right, above it on the bench is the battery of Leyden jars which form the capacity of the primary oscillatory circuit. Mounted on the jar rack will be seen the spark gap with the inductance wound round the muffling chamber. On the wall at the back of the cabin is the antennæ change-over switch. This switch when in the up position connects the antennæ and earth to the receiving apparatus and breaks the power circuit. When it is in the down position it breaks the antennæ and earth connections from the receiver and completes the power circuit. The receiving apparatus is on the table toward the left and the Morse key to the right.

POULSEN SYSTEM

The Poulsen system is based on the discovery of Mr Duddell that if a direct current arc is shunted by a circuit containing capacity and inductance there

will be established in the circuit electrical oscillations, the frequency of which depends upon the value of the inductance and capacity. The reason of this is that unlike a metallic conductor the arc does not follow Ohm's law and the curve showing the relation between current and terminal voltage is not a straight rising line, but has what is termed a falling characteristic—that is to say, if the current through the arc be increased the potential difference at its terminals will drop. Suppose now that a circuit with capacity and inductance in series is placed across the terminals of an arc, the condenser will charge, and in doing so, the current through the arc being lessened, the potential difference at its terminals will increase and charge the condenser to a still higher voltage. After the capacity is fully charged the current through the arc will increase, and, owing to the drop in voltage which it causes the condenser will discharge across the arc, and the discharge will, if the resistance is small, be oscillatory. In order to obtain oscillations of considerable energy Mr Duddell found that it was necessary to use a capacity of the order of one microfarad, and with a capacity of this magnitude it was not possible to obtain the very high frequencies needed for Radio-Telegraphy.

Poulsen's great discovery was the effect of a hydrogen atmosphere which by cooling the arc increased the steepness of its characteristic curve, and also the use of a very powerful magnetic field which enabled him to get a high terminal voltage. By the use of the arc burning in a hydrogen atmosphere, and the powerful transverse magnetic field, he was able to use a small capacity and thus get oscillations of the frequencies useful for Radio-Telegraphy and at the same time powerful. The practical construction of the Poulsen arc is as follows:—the anode is made of copper and the end takes the form of a beak (Fig. 48). The cathode is of carbon about one inch in diameter,

the arc striking between the copper beak and the edge of the carbon. The carbon is fitted in a holder which is slowly rotated by means of a small motor and as it burns away a fresh surface is presented and the length of the arc kept constant. The arc length

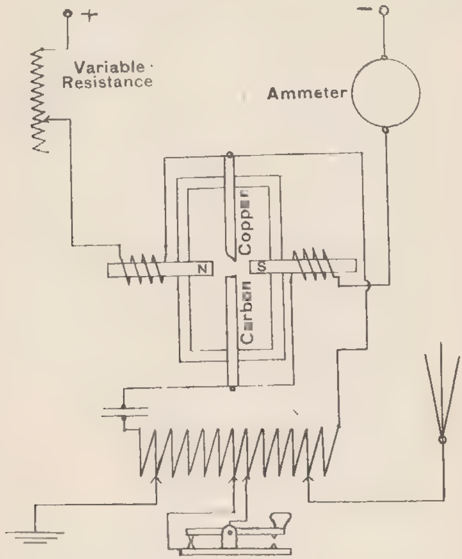

FIG. 48

Arrangement of circuits, Poulsen transmitter

is also adjustable by means of a screw fitted to the copper electrode.

The electrodes are taken through insulating sleeves in the sides of a water-cooled metallic chamber which is also flanged on the outside to assist the cooling. Through the sides of the chamber, and transversely to the electrodes, pass the pole pieces of a powerful

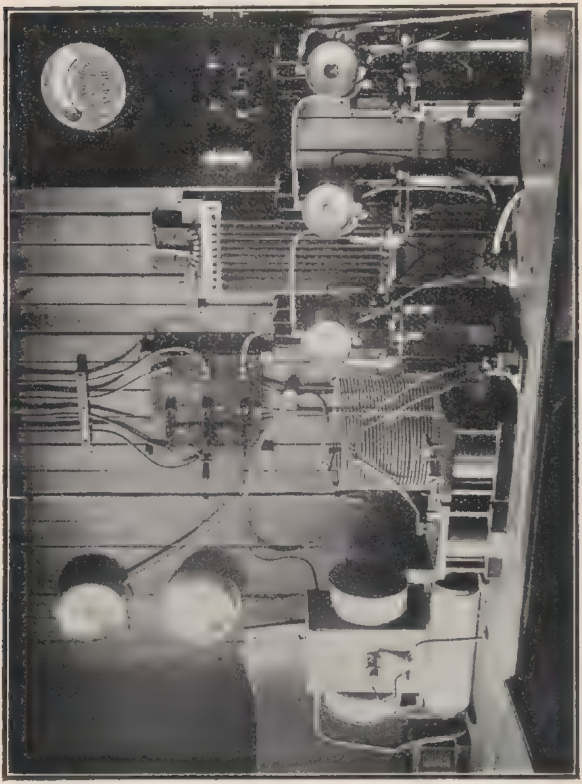

Photo *Topical*

FIG. 49

Poulsen transmitter (old type)

electro-magnet which blows the arc out into a loop, the winding of the magnets being in series with the arc also serve as choking coils and prevent the oscillations from passing back into the supply circuit. The chamber in which the arc burns is supplied with hydrogen through a tube let into its base and after passing through the chamber escapes through an outlet at the top and is conveyed away by means of a tube connected to it. The arc is connected across a 500 volt direct-current supply and across it is shunted

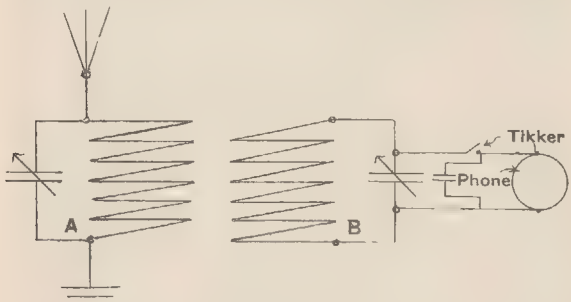

Fig. 50

Connections of Poulsen receiver. Tikker method

the primary circuit, which consists of a condenser and an inductance in series. The antennæ is connected to one point of the inductance and the earth wire to another. Signalling is effected by shorting through the Morse key a turn or two of the inductance which alters the wave length and throws the transmitter in and out of tune with the receiver, a difference of about 5 per cent. being sufficient. As energy is supplied to the antennæ at every swing the oscillations emitted from the Poulsen generator are continuous and undamped, or practically so. The

receiving arrangement used in conjunction with the Poulsen transmitter is unlike that of any other

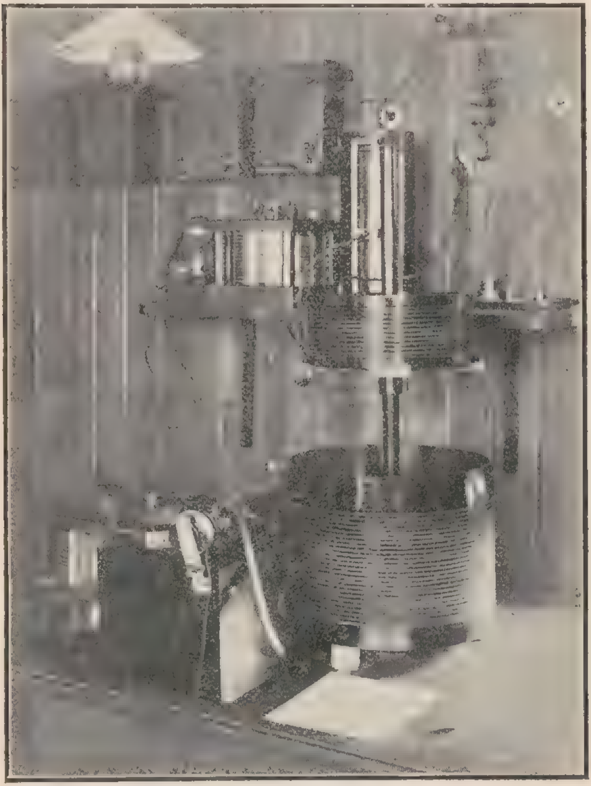

Photo FIG. 51 *Topical*

Poulsen tikker receiver

system inasmuch as no detector is made use of, but the received energy accumulated in a condenser and

discharged at intervals through the telephone by means of a piece of apparatus which the inventor has named a tikker. Fig. 50 shows diagrammatically the receiving circuits. A is the primary coil with variable condenser across its terminals to adjust the tuning; coupled to this coil is the secondary circuit B, which consists of a coil and a variable condenser; across the terminals of this condenser is joined a mica condenser of fairly large capacity and the tikker, which is an intermittent contact formed by two gold-plated brass wires crossing each other at right angles, one of them being mounted at the end of a small electromagnetic make and break similar in construction to a trembler bell. The telephone, which is of low resistance, is joined across the mica condenser. The action of the tuner is as follows :—The primary having been tuned to the sending station and the secondary tuned to the primary; during the intervals when the tikker contacts are open the secondary circuit is left free to resonate up, and the energy of many oscillations thus accumulated is, upon the closing of the tikker contacts, transferred to the mica condenser of large capacity which discharges it through the telephone. The coupling between the primary and the secondary is very loose, and full use is thus made of resonance, the tuning being so sharp that a difference of 4 or 5 per cent. in wave length is sufficient to render the signals inaudible. The tikker method, although one of the most sensitive means known for detecting electrical oscillations, labours under the disadvantage that it is not able to receive signals from the ordinary spark transmitters which give out damped and discontinuous oscillations.

Photographic Recorder

Valdemar Poulsen, in conjunction with his assistants, has devised a very sensitive recorder capable of

recording signals at a high rate. It consists of a string galvanometer composed of a very powerful electro-magnet between the poles of which is stretched an exceedingly fine gold wire. The image of the wire is by means of a microscope magnified and thrown on to a moving strip of sensitised paper. If now signals actuate the thermo-detector it will pass a current through the fine wire to which it is joined, and the wire will be deflected and the position of its image on the tape will be altered; it will thus be seen that the recording of a dot or a dash depends upon the time which the wire is displaced from its position or rest.

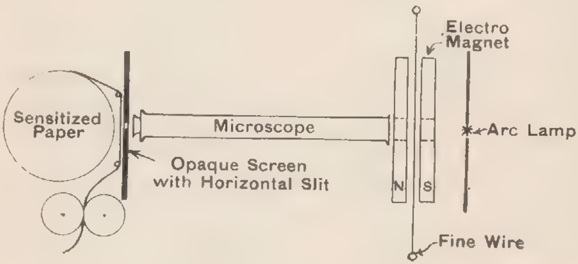

Fig. 52

Poulsen photographic recorder

The tape after recording the signals passes through a tank containing developer and then through one in which is contained the fixing solution. Fig. 52 shows the arrangement of the apparatus and Fig. 53 a specimen of the tape. On the actual tape, however, the signals appear white on black.

Lepel Quenched Spark System

The quenched spark method of exciting electrical oscillations, of which the Lepel system is an example, is based on the experimental work of Professor Wien.

While making experiments on two coupled circuits, the primary or exciting circuit of which contained a very short spark gap, he found that in place of the usual coupled waves only one existed, the wave length of which was determined solely by the capacity and inductance of the secondary circuit. This is no doubt due to the fact that, when the length of the spark gap is very small and the size of the electrodes large compared with it, the primary oscillations are rapidly damped out, and probably cease to exist at the end of two or three swings, and the energy being transferred to the secondary circuit, and the coupling broken, the secondary circuit is left free to vibrate in its own natural frequency. Owing to the cooling of the gap and the consequent restoration of its high resistance there is no reflux back from the primary to the secondary as occurs in the ordinary coupled spark transmitters.

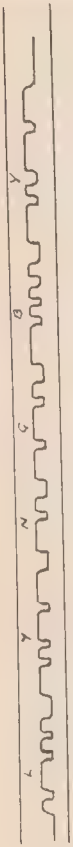

Fig. 53

Specimen of tape—Poulsen photographic recorder

This method of generating electrical oscillations is surprisingly efficient: the efficiency claimed for it being as high as 85 per cent. The result of independent experiments gives the efficiency at from 45 to 50 per cent., which is probably nearer the mark, and even at this figure it is far in advance of the older methods. Fig. 54 shows diagrammatically the arrangement of sending circuits as used by the Lepel Syndicate. Across a 500-volt direct-current supply is joined the spark gap, the positive electrode being made of pure electrolytic copper, and hollow to admit

of water cooling: the negative electrode is made of delta metal and backs on to a water-cooled chamber. The electrodes are held apart by one or two paper discs (Fig. 55) having a circular hole punched out in the centre. By this method the spark length is automatically set and the slow combustion of the paper allows a clean surface for the spark to pass, which greatly improves the regularity of the working. Across the

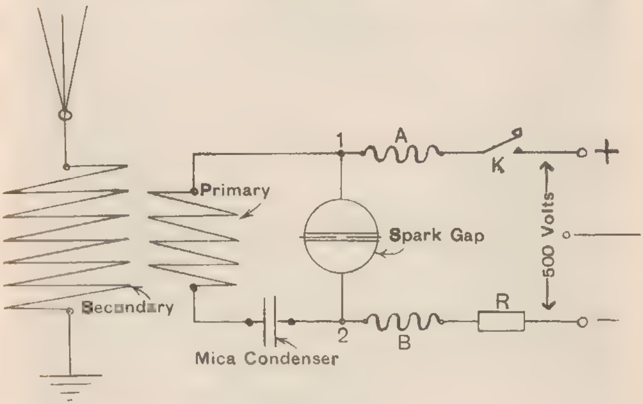

Fig. 54

Lepel transmitting circuits without musical note device. A and B = choking coils. K = Morse key. R = resistance

spark gap is shunted a circuit consisting of one or more turns of inductance which in the case of the Lepel system takes the form of a flat copper tape of large surface wound on a cylindrical former, and a condenser made from copper foil with mica dielectric. The capacity of this condenser, it is found, should be kept rather large, something of the order of 100,000 centimetres being used. To the primary circuit is electromagnetically coupled a secondary circuit, the

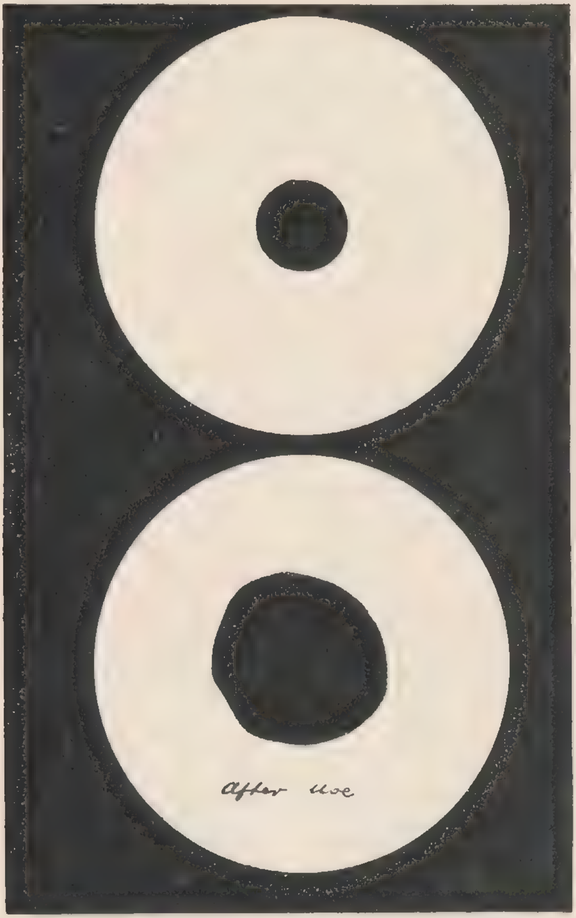

FIG. 55.—Paper discs used in Lepel spark gap

ends of which are joined to antennæ and earth respectively. A and B, Fig. 54, are choking coils. K is the Morse Key and R is Resistance built up of

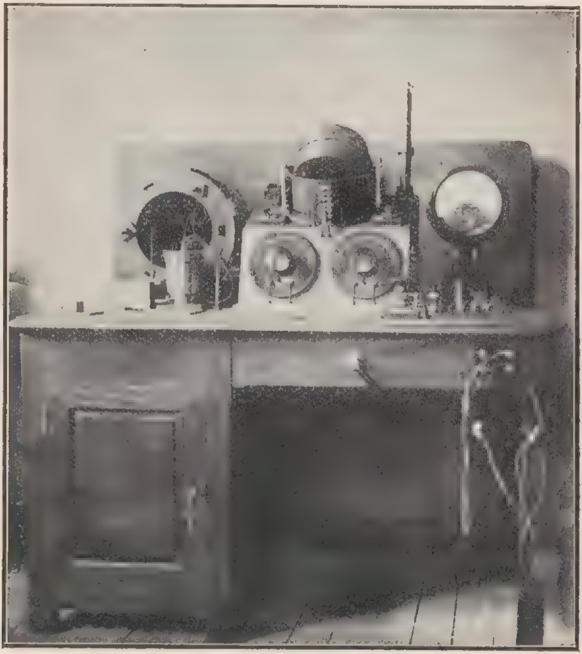

FIG. 56

Complete Lepel installation. The musical note device, choke coils and resistances are installed in cupboard to the left of photograph

iron filaments enclosed in glass bulbs containing a hydrogen atmosphere. This form of resistance, which the reader will no doubt recognise as being similar to those used in the Nernst Lamp, constitutes

a constant current device, and should the spark gap from any cause become shorted the lamps at once increase their resistance and prevent the current from rising to dangerous proportions.

The oscillations emitted from an arrangement of this kind are very feebly damped, the decrement being as low as ·04 and are so nearly continuous that the effect on a receiver is that the signals are only audible as a faint blowing sound and probably could not be detected at all at any great distance unless some form of interrupter was inserted in the receiver to cut up the current through the telephone. By an ingenious application of Mr Wm. Duddell's discovery that a direct-current arc would, if shunted by a circuit containing capacity and inductance, emit a musical sound, the frequency of which corresponded to the electrical frequency of the circuit, the inventor has greatly extended the utility of the apparatus, inasmuch as by the use of the Duddell circuit the signals can be given out as pure musical notes and are thereby rendered distinctly audible in the receivers employed in ordinary spark installations. Each Lepel station is also fitted with a keyboard giving the operator a choice of eight notes so that it is possible to play simple tunes with the same ease as signals are sent. The receiver is of the three-coil type and is shown in Fig. 60. The primary coil is connected to the antennæ and earth and has across its terminals a variable capacity by means of which the tuning is

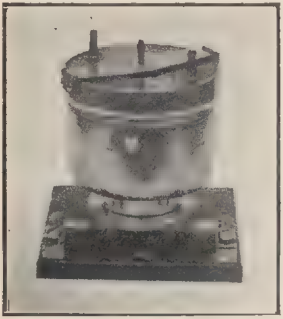

Fig. 57
Lepel spark gap

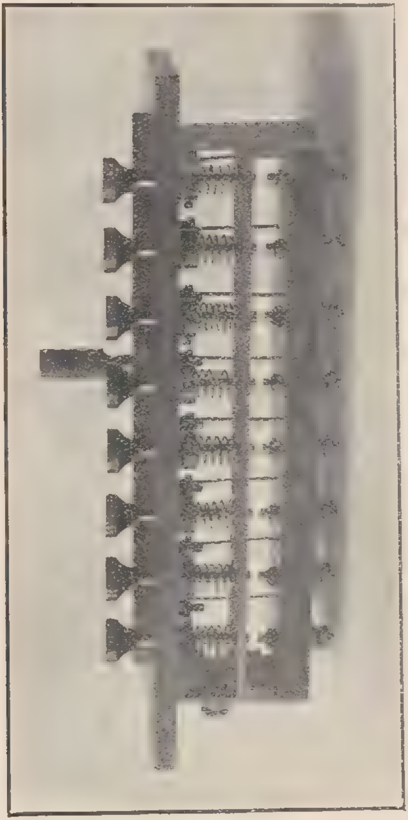

Fig. 58
Piano keyboard

effected. The inductance of the primary coil is also

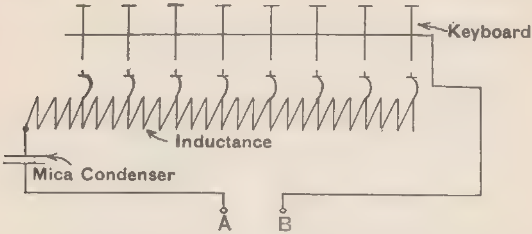

Fig. 59

Musical note apparatus. Terminals A and B are connected to 1 and 2, Fig. 54. The coil is not coupled to either primary or secondary

variable in several steps. Coupled to the primary is the secondary circuit, which consists of a coil

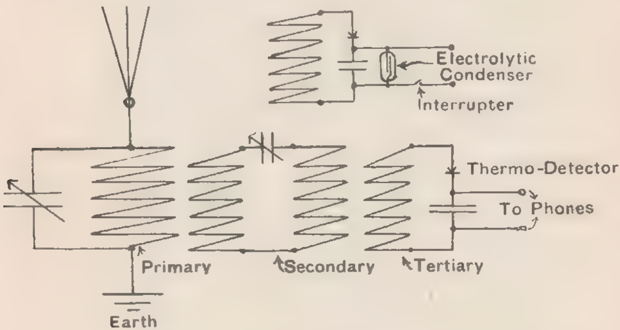

Fig. 60

Lepel receiver, arrangement of circuits for reception of spark signals. Inset shows modification to receive undamped waves

variable in steps and a variable condenser. The

tertiary circuit, which contains the detector, is inductively coupled to the secondary. The detector is of the thermo-electric variety and consists of a graphite point resting against a piece of galena. The receiver can be arranged for the reception of signals from ordinary spark senders and from Lepel stations using musical notes, or for the reception of the undamped oscillations from a Poulsen transmitter, or from a Lepel set working without musical-note device. The change is effected by simply moving to one side or the other a two-way switch; when it is desired to receive signals from a spark sender the

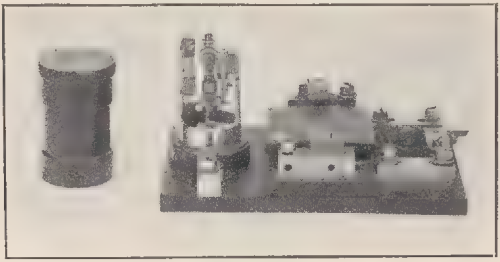

FIG. 61

The detector (cover removed)

switch is placed in a position such that the tertiary circuit is made up of the coil joined in series with a small blocking condenser and the detector; the phones being joined across the terminals of the condenser. When it is desired to receive the undamped waves the switch is placed in the alternative position, when the circuit is composed as follows:—In parallel with the blocking capacity is connected a piece of apparatus known as an electrolytic condenser. It consists of two pieces of foil about three centimetres in length by one in width immersed in an electrolyte and sealed into a glass tube, the wires

by which connection is made to the foil strips passing out through the walls of the tube. One lead of the telephone is also broken and a small intermittent contact, consisting of two gold wires crossing each other at right angles, inserted. The action of a receiver arranged in this way is as follows:—On the oscillations passing across the graphite galena junction it is heated and a small direct potential difference is created at its terminals. This potential difference acting on the electrolytic condenser polarises it—that is to say, a very thin film of hydrogen is deposited on the foil plates; this film constitutes

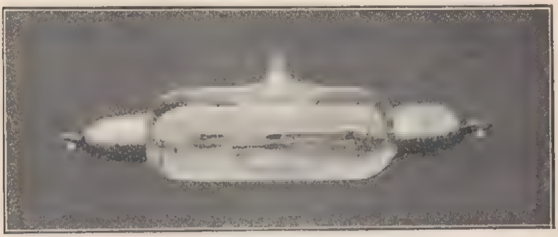

FIG. 62

Electrolytic condenser

the dielectric of the condenser and being microscopically thin the capacity is enormous, something of the order of two microfarads. After polarising it, and thereby making it a condenser, the thermo junction charges it, and this charge is sent through the telephone receiver every time the interrupter makes contact.

It will be seen that, like the Poulsen tikker arrangement, this is an integrating receiver—that is to say, the energy of the oscillations is collected over a given short period, determined by the speed at which the interrupter is running, and then discharged through the telephone, producing an enhanced effect. It

FIG. 63
The interrupter (cover removed)

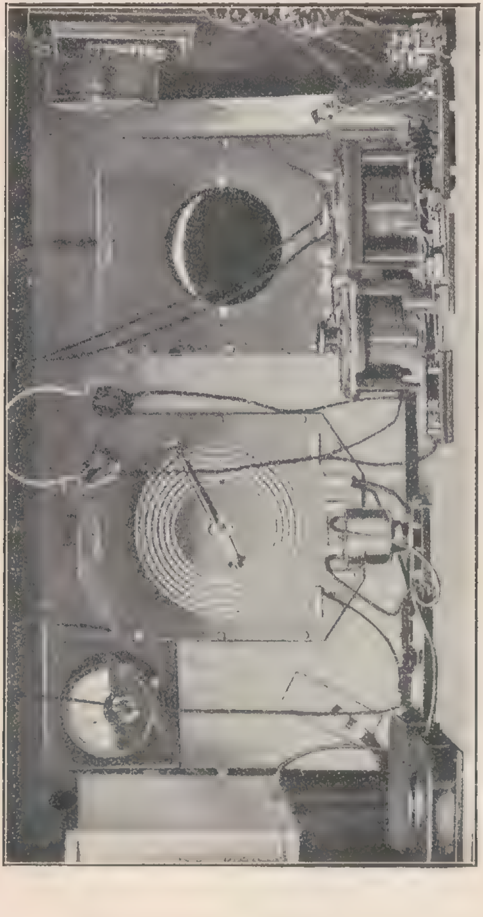

Fig. 64

Lepel military station. Interior of instrument cart showing entire transmitting and receiving apparatus

likewise enables a much looser coupling to be employed and so renders it somewhat more free from the interruption caused by badly damped waves and from atmospherics.

TELEFUNKEN SYSTEM

(*Quenched Singing Sparks*)

This system, like that of Lepel, is based on the experimental work of Professor Wien, but while the Lepel Company favour low-tension direct current with a single gap the Telefunken Company use high-tension alternating current and a number of gaps in series. Fig. 65 shows a typical small power ship station capable of working over a distance of one hundred miles or so. It will be seen that the whole of the apparatus is mounted in a cabinet and occupies very little space. The primary circuit is made up of the Morse key, variable resistance, and the primary of the induction coil joined in series across the supply mains. Across the secondary of the induction coil is the multiple spark gap, consisting of six gaps between copper plates held apart by mica rings, and across this spark gap is the primary oscillation circuit composed of Leyden jars and a portion of the flat spiral inductance. The antenna with a variable inductance working on the variometer plan in series with it is connected to one point of the primary inductance and the earth wire to another. As explained in the preceding chapter, the oscillations in the primary circuit are rapidly damped, and owing to the cooling of the gap there is no reflux back from the antennæ circuit to the primary. Only one wave therefore exists, as after the primary has transferred its energy to the antennæ the coupling between them is broken and the secondary or antennæ circuit is left free to oscillate in its own natural period. The

efficiency is remarkably high, being about 50 per cent.,

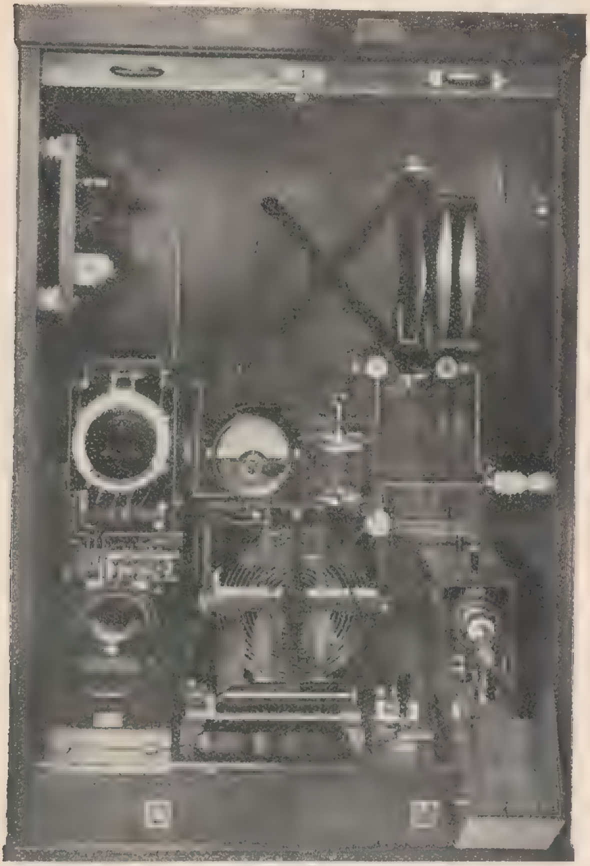

FIG. 65
Small ship's installation mounted in cabinet

and the damping of the oscillations emitted is very

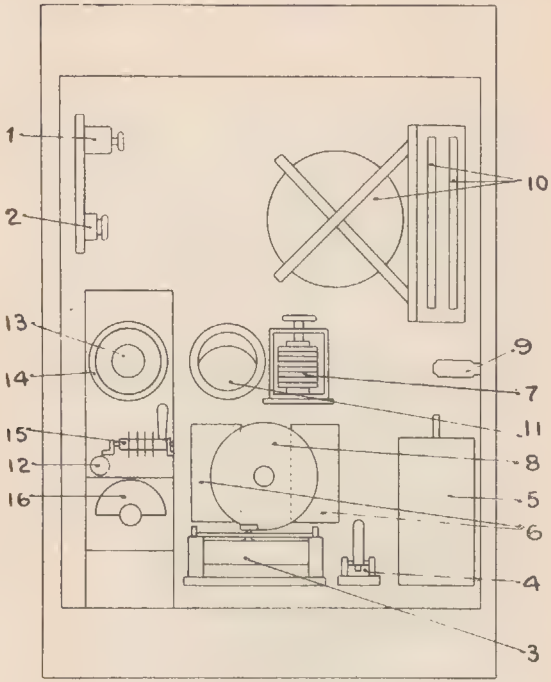

FIG. 66

Key to Fig. 65

1. D.C. switch
2. D.C. fuse
3. Variable resistance
4. Morse key
5. Induction coil
6. Leyden jars
7. Spark gap
8. Inductance
9. Aerial leading in insulators
10. Aerial tuning coils
11. Ammeter
12. Detector
13 and 14. Primary and secondary of receiver
15. Multiple switch
16. Variable condenser

low. In the larger stations built by the Telefunken Company the induction coil is replaced by an alternat-

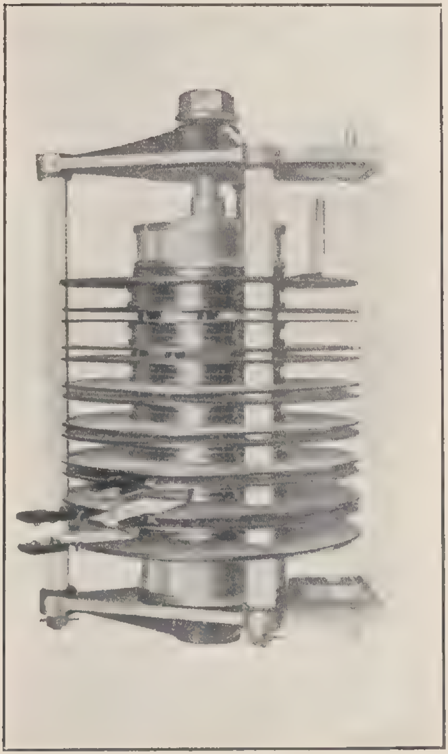

FIG. 67
Telefunken quenched spark gap

ing current transformer and a motor generator to supply it with current. This, with an increase in the

number of gaps, is practically the only difference between the small and large power sets.

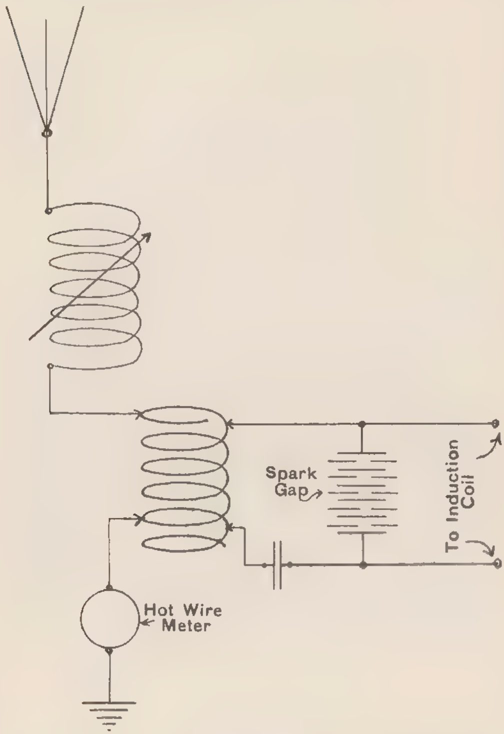

FIG. 68

Arrangement of circuits. Telefunken quenched spark transmitter

The receiving arrangements are shown diagrammatically in Fig. 69. P is the primary coil to

which the antennæ and earth are connected and across which is shunted a variable condenser; the coil is variable in three steps. Inductively coupled to the primary is the secondary circuit S, which contains the detector, the latter being of the thermo-electric type. It will be noticed that unlike most of the inductively coupled tuners there is no intermediate circuit, the detector circuit being coupled directly to the primary, the Company being of opinion that any advantage arising from the use of the intermediate circuit is more than compensated for by the

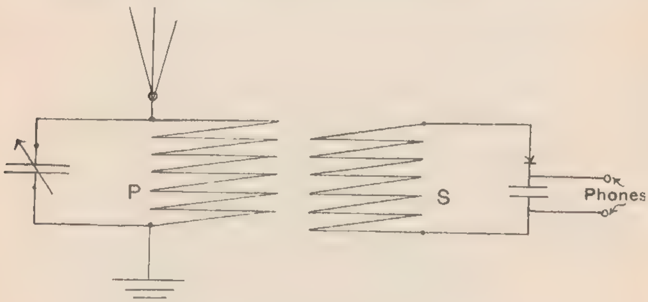

FIG. 69
Arrangement of circuits. Telefunken receiver

increased simplicity of their arrangement, which has only one variable for the operator to attend to.

CALLING-UP APPARATUS

The Telefunken Company supply with their stations a call-up device the construction of which is very ingenious. The following is a description of the apparatus :—The pointer of a well-balanced moving coil galvanometer, having a sensitiveness of 1×10^{-7}, is deflected by the current from the detector, if the

current lasts for about ten seconds—*e.g.* if the transmitter sends an uninterrupted dash for ten seconds. If the duration of the dash is much shorter, as when Morse signals are being sent, a suitable deflection is not obtained owing to the inertia of the galvanometer.

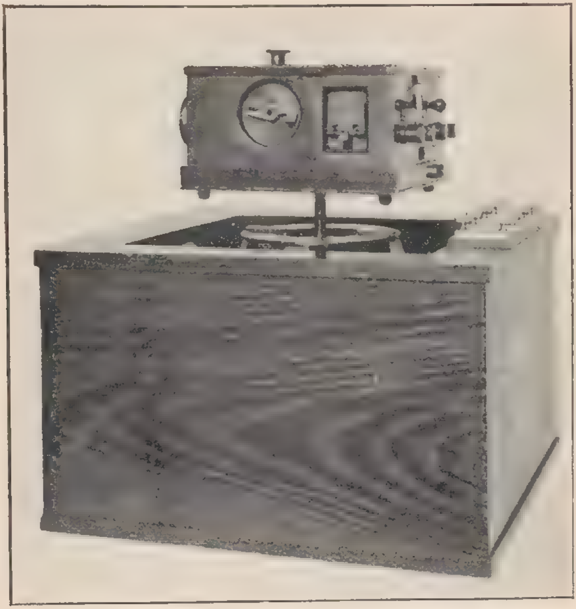

FIG. 70
Telefunken call apparatus

When the pointer is deflected it engages in a toothed wheel which is continuously revolved by clockwork and is depressed by it, thus closing a circuit containing a trembler bell which gives the alarm. The pointer is released by means of a lever movement when the call is answered by the operator.

Fig. 70 shows the apparatus as supplied to ship stations mounted in cardan suspension.

Telefunken Sound Intensifier

The purpose of the sound intensifier is first, by means of mechanical tuning, to select signals of a given tone or spark frequency and then to intensify them. This is achieved in the following manner:—the pulsating current which is given out by the detector when it is actuated by signals passes through the coils of an electric magnet wound to a high resistance. The magnet is provided with a light armature with an accentuated natural period corresponding with that of the tone to be received. Against the armature is pressed a microphonic contact in series with which is a dry cell and the winding of a similar magnet, the armature of which is stimulated into vibrations of greater amplitude by the intensified current which is sent through its coils. It is the usual practice to step up the current three times and at the third intensification to pass the current through a loud-speaking telephone. With a triple intensification the current can be increased from 10^{-7} to 10^{-2} ampères and the signals rendered so loud as to be audible at a considerable distance from the telephone.

For ship working the intensifier is suspended in a well sprung and damped cardan suspension, and it is claimed that the apparatus requires little adjustment and remains constant for long periods. By the insertion of a small transformer and a rectifying detector it is also possible to work a Morse printer and thus obtain the advantage of a permanent record without sacrifice of distance. The diagram shows connections for reception either by printer or telephone.

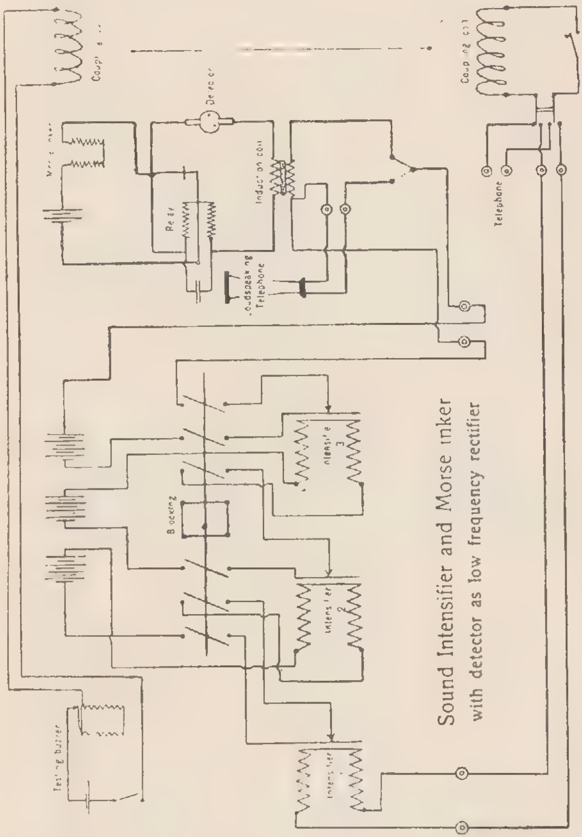

FIG. 71
Connections of Telefunken sound intensifier

CHAPTER VI

Atmospheric Eliminator—Telephone Relay—Variometer

Atmospheric Eliminator

At certain times the atmosphere is highly charged with electricity, more especially is this the case in tropical climates, but even in a temperate climate the interference caused to radio-telegraphs by these atmospherics is at times so great as to render working impossible.

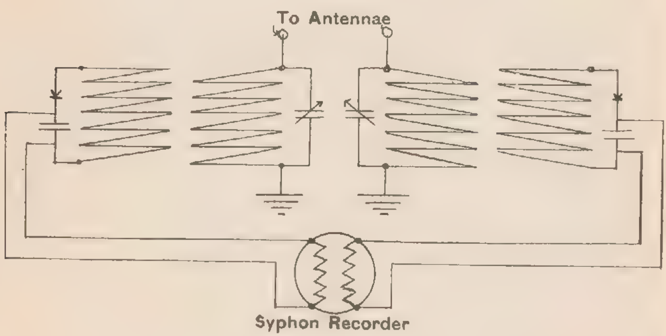

Fig. 72

Arrangement of circuits. Atmospheric eliminator

Many attempts have been made to eliminate these atmospheric disturbances, one method being to make the receiver insensitive and to use correspondingly higher power at the transmitting station. Another method was to provide an alternative path for the

atmospheric discharges placed as a shunt to earth. Neither of these methods, however, were completely satisfactory. Fig. 72 shows a solution of the problem put forward by the writer some years ago. It consists of two complete receivers, one tuned to the frequency of the oscillations to be received, the other tuned to a slightly different period. The detectors, which are of the thermo-electric variety, are joined to a syphon recorder having two coils. It will be seen that atmospherics, or even badly damped oscillations, will act equally on the two receivers and as the coils of the syphon recorder are wound in opposite directions the currents from the two detectors will neutralise each other and no record will be made on the tape. If, however, sharply tuned oscillations are sent out from the transmitting station, they will only affect the receiver which is tuned to them, and the detector in that circuit being more strongly excited a larger current will flow through the coil of the receiver which is connected to it, and consequently it will deflect and record the signals. Such a device, however, should only be used to receive oscillations which are undamped, for the reason, as stated above, that badly damped oscillations will actuate both circuits and consequently will not be recorded.

The Telephone Relay

This instrument, the invention of Mr S. G. Brown, has for its object the stepping up or magnification of feeble telephone currents, thus rendering them more audible.

It consists of a novel kind of microphone formed of two pieces of hard osmium iridium alloy, separated to an infinitesimal degree by the adjoining screw W (Fig. 73) and by the action of the local current which flows through it and the winding K (Fig. 73). The local current assists in forming the microphone by

rendering the small space between the contacts conductive and after the relay has been actuated by the passage of current through the winding H it restores it to its original adjustment by means of the regulating winding K.

Fig. 73 shows clearly the construction of the relay.

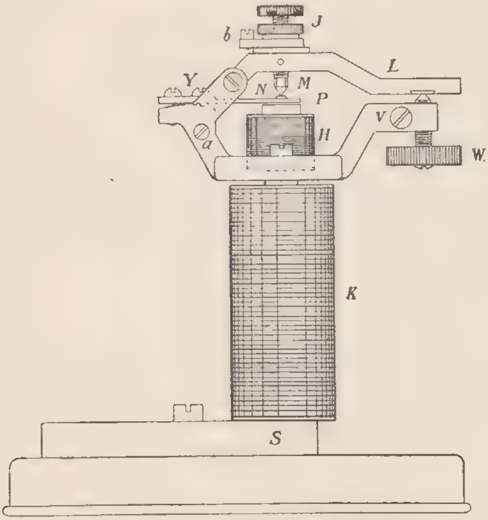

Fig. 73
Side elevation of Brown telephone relay

Fig. 74 gives an enlarged view of the microphone contacts and shows the position the reed should occupy with regard to the magnet H. Fig. 75 shows the connections of the relay : the terminals A should be connected to the receiving circuit in place of the ordinary telephones. The local circuit consists of the microphonic contacts, the regulating winding K, a

dry cell, milliampère meter and telephone receiver all in series. The working of the relay appears to be as follows :—Supposing the telephone current to be magnified circulates through the winding H in such a direction as to increase its magnetism the reed P will be pulled toward the magnet, and, the resistance of the microphone being thus altered, a sound will be heard in the telephones, and as the local current is taken through the winding K, in such a direction as to assist the magnetism of the permanent magnet, any opening of the microphonic contact and thereby increase of its resistance causes the current to fall,

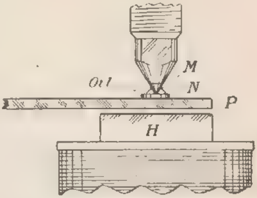

FIG. 74

Enlarged view of microphonic contacts

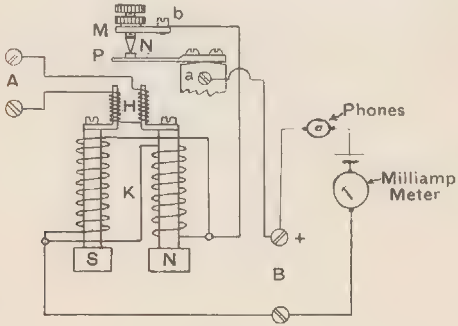

FIG. 75

Connections of Brown telephone relay

and the magnet thereby being weakened the reed P resumes its normal position. Also it will be seen that

should the current in the winding H be in such a direction as to oppose the permanent magnet, the microphone will lower its resistance owing to the removal of part of the force which is acting against the stiffness of the reed P and tending to hold the contacts apart and then, owing to the decrease in

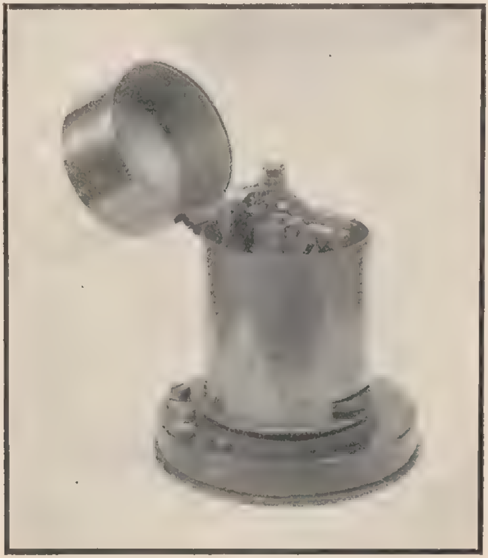

FIG. 76
The S. G. Brown telephone relay

resistance of the microphone and consequent rise in local current strength, the power of the magnet will be increased and the reed pulled back to the normal position. The inventor is of opinion that the resistance of the local circuit should not much exceed 6 ohms and that the voltage of the local battery should be ·5 of a volt. This voltage he obtained by putting

in opposition to each other a dry cell whose voltage was 1·5 and a 2-volt accumulator cell.

The writer however has obtained excellent results using phones whose resistance was about 60 ohms and a single dry cell. It was found that signals which were quite inaudible when the ordinary means of reception were in use could by the interposition of the relay be distinctly heard and when the signals were of average strength the use of the relay made them so loud as to be easily read at distances varying from 10 feet upwards from the phones.

A small drop of thin oil placed on the lower contact increases the reliability of the arrangement. It is also necessary to support the relay on a felt or rubber pad to protect it from outside vibration. For the same reason all connecting wires should be flexible as if they are solid and stiff the slightest touch causes them to vibrate and the vibration being transmitted to the relay is heard in the phone magnified many times. Using a voltage of 1·5 and phones whose resistance was about 60 the milliampère meter read from 10 to 15 milliampères when the relay was in the most sensitive adjustment.

The Variometer

The variometer is a form of variable inductance in which, however, the usual sliding contact is absent. It consists of two ebonite frames on which are wound the coils of wire. One end of each coil is connected by a flexible wire and the remaining ends are brought out to terminals; the inner coil is pivoted and is free to move about its vertical axis. It will be seen from Fig. 77 that when the inner coil is in the position shown the wire on the frames forms a continuous coil of two layers, the winding being all in one direction; this is the position of maximum inductance.

If, however, the inner coil be turned through 180 degrees it will be observed that the wire doubles back on itself and forms a bifilar or non-inductive winding: the variometer is usually provided with a pointer moving over a scale divided into 180 degrees. The advantages of this form of inductance are that sliding or rubbing contacts which often become dirty and thereby introduce a high resistance into the circuit are avoided, the inductance also is continuously variable practically from zero to a value determined by the dimensions of the coils, and occupies less space than the older types.

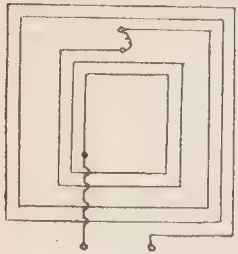

FIG. 77
Arrangement of coils in variometer

CHAPTER VII

MEASUREMENTS

Capacity—Insulation Resistance of Antennæ—H. F. Resistance—H. F. Currents—Wave Meters—Resonance Curves and Damping Decrements—Inductance—Coupling—Calibration of Receiving Circuits—Earth Plate Resistance—Strength of Received Signals

Capacity

The capacity of a condenser varies directly as the area of the opposing surfaces and inversely as the thickness of the dielectric or distance between the plates. The nature of the dielectric also has considerable influence in determining the capacity of a condenser. Supposing, for instance, that two plates, each having an area of 1000 square centimetres and the distance between the plates being ·1 of a centimetre its capacity K can be calculated from the formula $K = \frac{S}{4 \pi t} k$ (where S is the area of one of the plates in square cms. $\pi = 3{\cdot}1416$, t = thickness of dielectric and K = the dielectric constant which in the case of air is taken to be unity), and will be found to be 795 centimetres. If now the space between the plates be filled with mica the capacity will be greatly increased and in fact will be about five times as great as when the dielectric was air. This is due to the fact that various materials allow electrostatic induction to take place across them in varying degree. Thus mica permits it to take place about five times as well as air. The ratio

that exists between the capacity of two condensers of equal size, one having air for a dielectric and the other some other material, is termed the dielectric constant for that material and is denoted by the letter k. At the end of this chapter will be found a table of dielectric constants of the more usual materials used in condenser making, but it should be noted that different specimens of the same material often exhibit marked differences in the value of their dielectric constants, and that therefore the formula given above should only be used to calculate the value of an air condenser. If, however, we possess a standard condenser it is a simple matter to ascertain the value of an unknown capacity. Referring to Fig. 78, K is the known capacity; K_1 is the capacity to be measured. R and R_1 are variable resistances,[1] which must, however, be non-inductive and of small capacity, and T is a telephone receiver. To the points A and B an intermittent voltage is applied which may conveniently be done by joining in series a dry cell and quick-

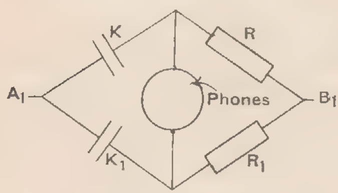

FIG. 78

[1] These resistances, as is perhaps well known to our readers, are built up of a wire doubled back on itself to form a non-inductive winding. In the case of the higher resistances it is necessary to use a considerable length of wire, which results in the coil having considerable capacity, and when used with a quickly pulsating current the coil would behave exactly as a condenser; to obviate this, the coil should be built up of a large number of smaller non-inductive resistances joined in series. When this is done it will be seen that the capacity is reduced to a minimum, as we are in effect joining a number of capacities in series.

Fig. 79
Practical form of De Sauty Bridge for capacity measurement

running interrupter and connecting them across the points.

On adjusting the resistance a point will be found at which the sound in the telephone will disappear or at least be a minimum. When this point is found a certain ratio exists between the condensers and the resistances such that $K : K_1 :: R : R_1$— that is to say, as K is to K_1, so is R to R_1 and the value of the resistances in ohms being known and also the value of the standard condenser it is a quite easy matter to find the value of the unknown capacity. This method is known as the De Sauty Bridge method, and is suitable for the measurement of capacities from a

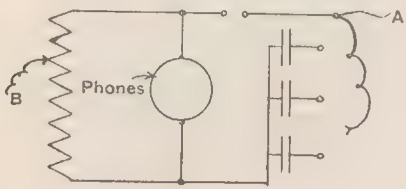

FIG. 80

Connections of De Sauty Bridge shown in Fig. 79

few hundred centimetres upwards provided that the capacity to be measured and the standard condenser do not differ by more than a small multiple. When the unknown capacity has a dielectric of different material to the standard it will sometimes be found impossible to obtain a complete cessation of sound in the phone owing to unequal absorption of the dielectrics, but in such cases the method can be depended upon to give results accurate to within a few per cent. Fig. 79 shows a convenient and practical form of the apparatus devised by the writer; in the box are three standard condensers whose values are 60,000, 10,000 and 1666 centimetres respectively.

The box also contains a quick-running buzzer which supplies the intermittent voltage necessary. The resistance is a standard resistance box reading to 1100 ohms in steps of 1 : the condenser to be measured is inserted in the clips on top of the box. Fig. 80 is a diagram of the connections. Another method suitable for the measurement of a small condenser is to join it in series with an inductance of known value and by means of a small Rhumkorff coil to cause the circuit so formed to oscillate, then by means of the wave meter the wave length is ascertained and the value of the capacity in microfarads found from the formula — WAVE LENGTH $= 59{\cdot}6 \sqrt{CL}$ where C = capacity in MFDS and L inductance in centimetres.

Dielectric Constants

Substance	*Dielectric Constant*
Sulphur	2·24
Ebonite	2· 0
India Rubber . . .	2·12
Gutta Percha . . .	2·46
Paraffin	1·98
Shellac	2·95
Mica	6· 0
Castor oil . . .	4·78
Turpentine . . .	2·15
Petroleum . . .	2·07
Glass (according to quality)	6· 6 to 9·8

Insulation Resistance of Antennæ

It is of the utmost importance that the antennæ should possess a high-insulation resistance, the measurement of which is made as follows :—Disconnect the antennæ from the circuit and connect it to one terminal of a very sensitive galvanometer

which has previously been calibrated; the second terminal of the galvanometer is connected to one pole of a direct-current dynamo or battery of cells giving a voltage of from 200 to 500 volts; the other pole of the dynamo is connected to the earth plate. Observe the current indicated by the galvanometer and the insulation resistance of the antennæ can then by the aid of Ohm's law be found. Thus, supposing the voltage of the dynamo to be 500 volts and the current indicated by the galvanometer 2 microampères, the insulation resistance will be found to be 250 megohms or 250,000,000 ohms. The insulation resistance will be found to vary greatly with the atmospheric conditions prevailing, thus it is much higher in fine dry weather than when the atmosphere is saturated with moisture.

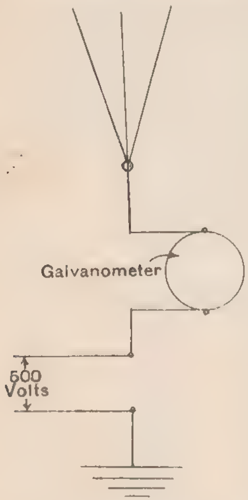

FIG. 81
Measurement of insulation resistance of antennæ

It should be noted that although the antennæ may have a very high insulation resistance it is not necessarily well insulated for oscillatory currents. To secure perfect insulation we must arrange that the antennæ does not run close to any earthed metal-work, and more especially that it does not run parrallel to it. If this is not done, oscillations will be set up in the earthed metal-work by induction from the antennæ and energy absorbed as effectually as if they were in actual metallic contact. It is for this reason that the guys supporting the mast of a Radio-Tele-

graph station are cut up into short lengths by means of insulators.

High-frequency Resistance

By Ohm's law the resistance of a conductor will vary as its length and inversely as its cross-sectional area, but this only applies to conductors carrying steady currents. The high-frequency resistance of a conductor is often very different from its resistance to steady or slowly alternating currents. The difference in the resistance will depend on the frequency of the alternations of current and upon the size or cross-section of the wire. A wire of large gauge will have a resistance many times higher for high-frequency currents than for a direct current, this is due to the concentration of the current on the outer skin and therefore to the reduction of the effective cross-section of the wire. If the wire were of a small gauge, say No. 38, the difference in value of the resistance for high and low frequencies would be very small, practically nil. For this reason many of the coils used in Radio-Telegraphy are made from laminated conductors—that is to say, a conductor built up of several hundred very small insulated wires. For the same reason they sometimes are made from tubes instead of solid wires. There is no convenient way for the operator to measure directly the high-frequency resistance, but if the coils are constructed as above they can be measured in the ordinary way on the Wheatstone Bridge and the high-frequency value will differ only very slightly from the value so obtained.

High-frequency Currents, Measurement of

For the measurement of high-frequency currents the ordinary hot wire ammeter is of no use, for the reason that it is constructed on the shunt principle—that is to say, the greater portion of the current to be

measured is diverted through the shunt, which is a stout copper wire or strip, and only a small known fraction passes through the wire of the meter. As explained in the chapter on High-Frequency Resistance, a thick wire has a much higher resistance to high-frequency currents than to steady or low-frequency currents, and therefore as the shunt consists of a stout wire its resistance would vary with the frequency of the current to be measured and it would thus be impossible to use such an instrument. A piece of apparatus known as a Reiss thermometer is however a suitable device with which to measure a high-frequency current. It consists of a bunch of fine bare wires connected between terminals and enclosed in a glass bulb; in connection with the bulb is a U-shaped stem containing a liquid coloured to make it easily visible. If now a direct current be passed through the bunch of fine wires they will be heated and in turn heat the air in the bulb, which will expand and drive the liquid up the tube. By passing various currents through the wires and noting the height to which the liquid rises in the tube for each current the instrument can be calibrated in ampères. The heater, being formed of a number of fine wires in parallel, will have the same resistance to high and low frequency currents and is therefore suitable for the measurement of a high-frequency current.

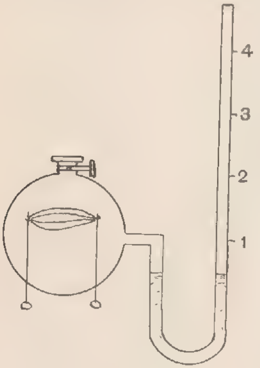

Fig. 82
Reiss thermo-galvanometer

Fig. 82 shows a Reiss thermometer. If such an instrument is not available the high-frequency current can be roughly measured by inserting in the circuit a piece of fine wire and noting how many strands in parallel the current will melt. Having ascertained the number, take the same number and pass through them a direct current, increasing it till they melt and noting on the ampère meter, which should be joined in the circuit with them, the current at which they melt. This current will be equal to the high-frequency current the value of which it is desired to know.

Wave Meters

This important piece of apparatus consists essen-

Fig. 83.—Marconi wave meter

tially of an inductance and a capacity, either or both

of which are variable, the frequencies or wave lengths corresponding thereto for the various positions of the pointer on the condenser scale, or, if the inductance is variable, on the scale of the inductance, having been predetermined and either plotted as a curve or arranged in table form. In the commercial form it is usual to have a fixed inductance or perhaps one variable in two or three steps and a condenser whose capacity is continuously variable between limits determined by its dimensions and the nature of its dielectric. Means must also be provided to make

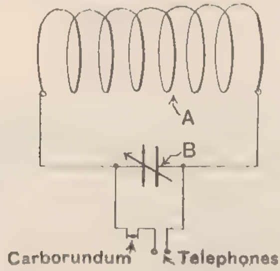

FIG. 84
Connections of Marconi portable wave meter

evident the attainment of resonance. The Marconi Company manufactures a very convenient and portable form of wave meter (Fig. 83). It consists of a coil of wire wound on a rectangular wooden frame and mounted in the lid of the carrying case, the ends of the coil are connected to the terminals of a variable condenser, and across the same terminals are shunted a telephone receiver and carborundum crystal; the connections are shown diagrammatically in Fig. 84, where A is the coil, B the condenser, C the carborundum crystal, and T the telephone. To measure the wave length of any given transmitter the key is

closed and the phones of the wave meter being placed on the head of the observer the condenser is

Fig. 85

adjusted until the sound is at a maximum; the wave length is then read from the table in the lid of the

box, which gives the wave lengths corresponding to every degree of the condenser scale. Such an instrument as the above, although very convenient for the determination of wave lengths, cannot be used for the measurement of the damping of the oscillations, as it is not possible for the ear to estimate the relative value of different currents which is necessary to the finding of the decrement of the oscillations.

A different pattern of wave meter must therefore be used. Fig. 85 shows an instrument suitable for the plotting of resonance curves and for the measurement of decrements. It consists of the usual coil and variable capacity, but in place of the telephone and carborundum crystal is a small hot wire meter. This meter, however, is not put across the condenser, but in series with it and the coil (Fig. 86). The scale is calibrated by means of a direct current and therefore shows the R.M.S. value of the oscillations; by squaring the readings on the scale, the mean square value can be obtained. Provision is also made for the insertion of a small resistance by means of which the damping of the wave meter itself can be eliminated, but as this is small it can as a rule be neglected.

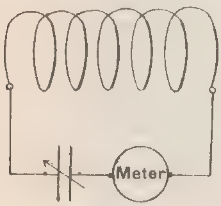

FIG. 86

RESONANCE CURVES AND DAMPING DECREMENTS

To plot a resonance curve the wave meter should be set up in proximity to the transmitter and the condenser adjusted till resonance is obtained, which will be indicated by the hot wire meter giving its maximum reading. The coil of the wave meter must be placed in such a position that the reading on the meter comes

just within the scale, say three parts over. The resonance wave length and the mean square value of

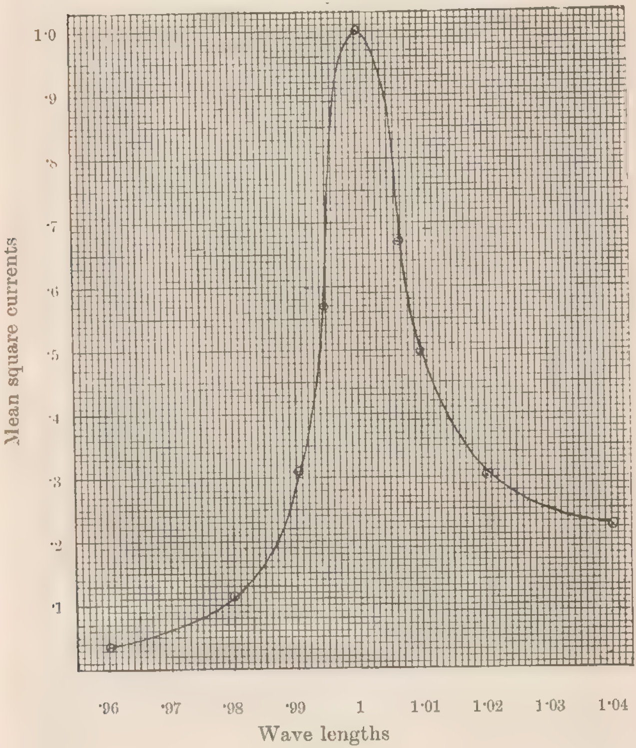

Fig. 87

Resonance curve

the current at resonance are noted; the mean squares of the currents for several wave lengths differing not more than 5 or 6 per cent. from the resonance

wave length are then ascertained. Thus, supposing the latter to be 500 metres it would be necessary to set the wave meter at the following wave lengths :—475, 480, 485, 490 on one side and 505, 510, 515 and 520 on the other side of it, and to find the mean square value of the currents corresponding to them. Calling the resonance wave length 1 and the mean square value of the current at resonance also 1 the other wave length and currents are reckoned as percentages and plotted as a curve which will assume the form shown in Fig. 87. From a curve so plotted it is possible to tell at a glance whether the oscillations given out by the transmitter under test are badly damped or only feebly damped. If they are badly damped the curve will not be very steep—that is to say, as the resonance point is receded from the falling off of the current will not be very marked; but if the damping is small the curve will be very steep and any deviation from the resonance point will be accompanied by a big drop in current. The damping decrement can be found by the aid of the formula, $\delta_1 + \delta_2 = \pi \ x \sqrt{\frac{y}{1-y^2}}$. δ_1 is the symbol for the decrement of the oscillations, δ_2 for that part of it due to the wave meter itself, $\pi = 3{\cdot}1416$, x the difference between unity and any value of the ratio between the resonance wave length and any other and is read directly from the curve, and y is the ratio between the mean square value of resonance current and any other current. This value is also to be read from the curve. For use in the above formula several values of x should be taken and the values of y corresponding to them, and as the curve is not symmetrical, the value of y should be the mean of readings taken from each side of the curve. The values of x and of y so taken are to be averaged and the average value is the one to be used in the formula. That part of the decrement due to the wave meter

itself is very small and can therefore as a rule be neglected. In plotting the resonance curve of a coupled spark sender it will be found that the curve has a double hump due to the interaction of the primary and secondary circuits which produces oscillations of two frequencies, but the shorter wave length need not be taken into account as its damping is greater than the longer one, on which account the longer one is always used for the reception of signals.

Another and simpler method of ascertaining the sum of the decrements is to set up the wave meter as before described to observe the wave length and mean square value of the current at resonance, and then to observe the wave length at which the mean square value of the current is reduced to half. From the formula $\delta_1+\delta_2=$ [redacted] $\pi \frac{\lambda-\lambda_1}{\lambda}$, where $\lambda=$ resonance wave length and $\lambda_1=$ the wave length at which the mean square current is reduced to half, the sum of the decrements can then be found. For example, suppose that the resonance wave length is 600 meters and that the mean square current is reduced to one-half when the wave meter is set at 594 meters,

ERRATA

Page 106, *read* $\delta_1+\delta_2=\pi x \sqrt{\frac{y}{1-y}}$

instead of $\delta_1+\delta_2=\pi x \frac{y}{\sqrt{1-y^2}}$

Page 107, *read* $\delta_1+\delta_2=\pi \frac{\lambda-\lambda_1}{\lambda}$

instead of $\delta_1+\delta_2=2\pi \frac{\lambda-\lambda_1}{\lambda}$

itself is very small and can therefore as a rule be neglected. In plotting the resonance curve of a coupled spark sender it will be found that the curve has a double hump due to the interaction of the primary and secondary circuits which produces oscillations of two frequencies, but the shorter wave length need not be taken into account as its damping is greater than the longer one, on which account the longer one is always used for the reception of signals.

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Inductance

The unit of inductance is the Henry, equal to 10^9 absolute units and a coil of wire is said to possess unit inductance when the current through it varying at the rate of one ampère per second induces in it an electro-motive force of one volt. The henry is far too large a unit for the inductances employed in Radio-Telegraphy, it is therefore customary to use a sub-unit, the millihenry or the microhenry, which

equal one thousandth and one millionth of a henry respectively: the inductance is also frequently expressed in absolute units or centimetres. The inductance of a circuit from which all magnetic material is absent depends on its geometric form, but if magnetic material is present, as when the coil is wound on an iron core, the inductance is also a function of the current. The inductance to some extent varies with the frequency of the current alternations and the low-frequency or steady-current value is larger than the high-frequency value. The reason of this is, that as the frequency increases the current is no longer evenly distributed over the section of the wire, but tends to confine itself to the surface. Anything that upsets the equal distribution over the cross-section of the wire diminishes the inductance: the variation with differing frequencies is very marked in a closely wound coil, especially if it has more than one layer. The calculation of the inductance of a coil from its dimensions is very difficult and can seldom be carried out with any degree of accuracy. The following method of ascertaining the inductance of a coil will be found reliable and easy:—The coil to be measured is joined up in series with the spark gap of a small induction coil and a condenser of known value (Fig. 88) and by means of a wave meter the frequency or the wave length corresponding to it ascertained; then by the use of the formula $\lambda = 59{\cdot}6\sqrt{CL}$ (where λ = wave length in meters, C capacity in microfarads and L the inductance in centimetres) it is very simple to arrive at the value of the unknown inductance.

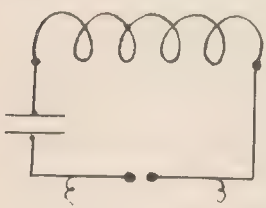


FIG. 88

Coupling

When two circuits are coupled together they react upon each other, as has been previously explained, and the ratio of the mutual inductance of the circuits to the square root of the product of the two inductances taken separately is termed the coefficient of coupling. The closest coupling theoretically would be 1, but in practice this is never attainable because the inductance is not wholly due to the coil but is distributed over the whole length of the antennæ. To ascertain the coupling coefficient the following procedure should be adopted. It is first necessary to find the mutual inductance; this may be done by setting the coils in position and joining them in series so that the current flows the same way in both coils. The inductance of the two coils so arranged is then measured as per instructions given in article on Measurement of Inductance: the coils are then joined in series so that the current flows in reverse directions in the two coils and the inductance again measured. The mutual inductance can then be found from the formula, $M = \frac{L_1 - L_2}{4}$, where M is the mutual inductance, L the inductance of the coils in the first position and L_2 the inductance of the coils in the second position. Having now ascertained the mutual inductance the next step is to measure the inductance of each coil separately when the coefficient of coupling can be found from the formula, $K = \frac{M}{\sqrt{LL_0}}$, where K equals the coupling coefficient, M the mutual inductance and L and L_0 the inductances of the two coils measured separately. In making the measurements of inductance the condenser joined up with them to form the oscillatory circuit should be variable to enable the same fre-

quency to be used for each measurement, the reason being that the value of the inductance of a coil varies somewhat with the frequency as previously explained in the article on Inductance. The coefficient of coupling can also be obtained from the formula, $\kappa = \frac{\lambda_1 - \lambda_2}{\lambda_0}$, where κ equals coefficient of coupling, λ_1 and λ_2 the wave lengths resulting from the coupling of the circuits and λ_0 equals the wave length of the circuits when the coupling is broken.

Calibration of Receiving Circuits

It is a great convenience to the operator to possess a calibration curve for his receiver, for suppose he is on the lookout for signals of a given wave length the position of resonance for which is unknown to him, he must be continually searching round till communication is established, which in the case of a ship may be many hours or even a day or two supposing she is delayed by unforeseen circumstances; whereas if he is in possession of the calibration curve he can at once adjust his circuits and then stand by. To plot such a curve he should proceed as follows:—If the receiver consists of two circuits he should excite one of them by means of a small induction coil, the second circuit meanwhile being uncoupled, and setting the pointer of the variable condenser in various positions, say every twenty degrees, or if it is the inductance that is variable the slider will be moved twenty or thirty turns at a time and by means of the wave meter the wave lengths corresponding to these positions found, the second circuit is then treated in like manner and the values so found are plotted as in Fig. 89. The curves will generally be found to be rather steep at the origin and then to flatten off toward the end. In using the curves it should be

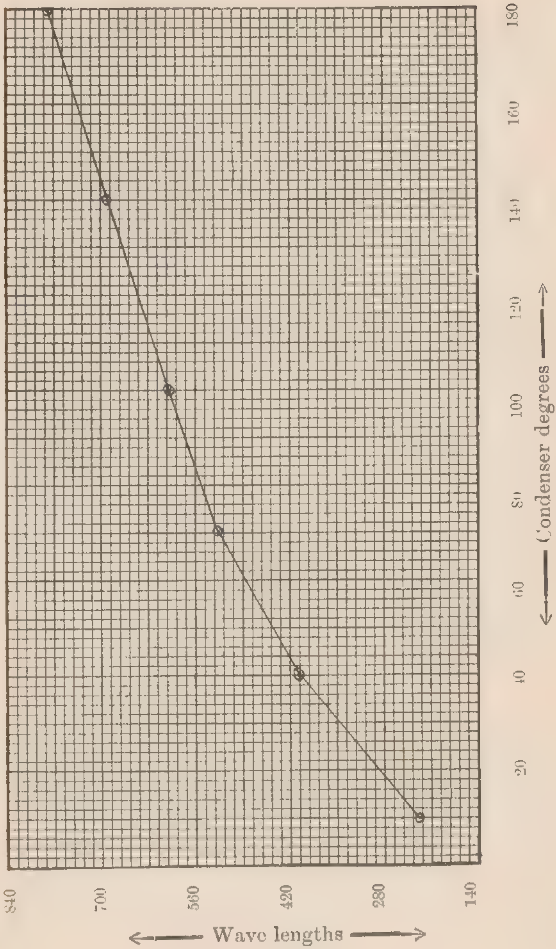

180
160
140
120
100
80
60
40
20
Condenser degrees
840
700
560
420
280
140
Wave lengths

FIG. 89

noted that when the coupling is re-established between the circuits it will slightly modify the wave lengths as shown on the curve but the difference in adjustment required to bring the circuits absolutely into tune will be very small.

Measurement of Earth Plate Resistance

The measurement of earth plate resistance is carried out as follows :—

In laying down the earth wires half should be brought to one terminal in the cabin and the other half to another terminal (normally, of course, these terminals are connected together); between these terminals a galvanometer and battery are joined and the current noted, the resistance can then be found by the aid of Ohms law $C=\frac{E}{R}$ $\therefore$ $R=\frac{E}{C}$, where C = current, as read from galvanometer, E = voltage of battery and R = the total resistance of the circuit. If the internal resistance of the battery is subtracted from this the remainder will be the earth plate resistance. In making the measurement it is advisable to use large secondary cells, as the internal resistance of these is negligible.

Strength of Received Signals

Assuming that the detector in use is of the thermo-electric type, the strength of incoming signals can be measured by means of a sensitive moving-coil galvanometer, which should be joined in place of the telephones. As, however, the signals are usually read from a telephone receiver and, as we have seen in a previous chapter, the telephone is most sensitive to certain frequencies, it will be seen that weak oscillations of the right frequency may produce a greater effect in the telephone than stronger oscillations of a

different frequency. In the majority of cases also it is only a comparison of the strength of signals that is required, in which case the shunted telephone method will be found to answer the purpose; the procedure is as follows:—A resistance variable in small steps is joined in series with a switch across the telephone terminals of the receiver. The operator at the sending station depresses his key and the observer at the receiving end having tuned the signals in to their maximum strength closes the switch and so puts the resistance in shunt to the telephones. Starting with the maximum resistance he decreases it step by step until the signals are just audible; then, knowing the resistance of the telephones and the resistance of the shunt the signal strength can be expressed as so many times audibility. For instance, supposing that the shunt resistance just equals that of the telephones, the current from the thermo-cell dividing as it dose in inverse proportion to the resistances of the two branches of the circuit, it is evident that half flows through the telephone and half through the shunt therefore the strength of signals can be expressed as two. Now suppose that the shunt resistance was such that nine-tenths of the current flowed through it, the signal strength in that case would be ten.

Wave Length

$$\lambda = 59{\cdot}6 \sqrt{\text{CL}}$$

Wave length in meters equals 59·6 times the square root of the product of the capacity in microfarads and the inductance in centimetres.

Oscillation Constant

$$\text{O} = \sqrt{\text{CL}}$$

The square root of the product of the inductance in

centimetres and the capacity in microfarads is termed the oscillation constant and is symbolised by O.

Frequency

$$n = \frac{5 \cdot 033 \times 10^6}{\sqrt{\mathrm{CL}}}$$

Frequency equals 5·033 times ten to the sixth divided by the oscillation constant.

Velocity

The velocity of electro-magnetic waves is identical with that of light and approximately equals 3×10^{10} centimetres per second: the relation that exists between velocity frequency and wave length is given by the formula, $\mathrm{V} = n\lambda$.

CHAPTER VIII

REGULATIONS AND INSTRUCTIONS FOR SHIPS AND STATIONS LICENSED BY H.M. POSTMASTER-GENERAL

Speed of Transmission

The speed of transmission must under normal circumstances be not less than twelve words per minute, five letters counting one word.

Power

The power imparted must not exceed one kilowatt under ordinary circumstances. Larger power may be used for signalling over 165 nautical miles, or if, by reason of intervening obstacles, communication can only be effected by an increase of power.

Wave Lengths

For ships the normal wave length is 300 metres, and every ship must be capable of working on this wave length; other wave lengths may be used if they do not exceed 600 metres. The wave lengths for coast stations are 300 metres, and 600 metres and every coast station open for public correspondence will use one or other of these wave lengths and will always be ready to receive calls on it. A coast station is sometimes authorised to use other wave lengths (not exceeding 600, or else exceeding 1600 metres) for communication of a special kind. Ships

may also be licensed for receiving messages from coast stations authorised to carry on long-distance communication by means of wave lengths exceeding 1600 metres, but are not allowed to transmit except on wave lengths of 600 metres or less.

Obligation to communicate with all Systems

All coast stations (except those exempted by their respective governments) are bound to interchange radio-telegrams with ships irrespective of the system of Radio-Telegraphy employed. Similarly ships are bound to interchange messages with coast stations without regard to system. British ships at present are not bound to exchange messages with other ships, whether British or foreign, except in cases of distress, when the obligation is universal and such messages must be given priority.

Minimum Power to be used

All stations are bound to exchange messages with the minimum power consistent with effective communication.

Priority of Messages

Priority must be assigned first of all to messages of distress, then to messages of the British Admiralty and other British Government departments and to the messages of other governments; then to service messages, and finally to ordinary correspondence. Ordinary messages take precedence according to their time of handing in.

Calling

As a general rule, it is the ship which calls the coast station. Generally the ship should not call until

within 75 per cent. of the normal range of the coast station; the wave length used must be the normal one of the coast station with whom communication is desired. Suppose a ship whose call signal is DHB wishes to call a station whose call is LNS, she would proceed as follows:—Having listened to ascertain that the station is not engaged the ship would signal — . — . — LNS LNS LNS — . . . DHB DHB DHB, and the coast station would reply thus: — . — . — DHB DHB DHB — . . . LNS — . — if she were ready to communicate; and if she were not, would reply assigning a time at which she would, in which case her reply would be as follows: — . — . — DHB DHB DHB — . . . LNS . — . . . 20 minutes . — . — .

If a station as the result of a thrice-repeated call does not reply the call may only be renewed after the lapse of half-an-hour. (This rule does not apply to cases of distress.)

Preliminary Correspondence

The ship first signals:

(1) Her distance from the coast station in nautical miles.

(2) The true bearing of the ship from coast station reckoned in degrees from 0 to 360.

(3) The true course of the ship in degrees from 0 to 360.

(4) The speed of ship in nautical miles per hour.

(5) The number of words which the ship has to transmit.

As regards the true bearing of the ship from the coast station, the degrees are reckoned "clockwise" from north, round through east, south and west. Thus if the ships bearing from the coast station are anything between north and east, the number to be signalled would be between 0 and 90 (A, Fig. 90);

similarly if it is between east and south the number would be between 90 and 180 (B, Fig. 90).

Between south and west the number would be between 180 and 270 (C, Fig. 90); between west and north the number would be between 270 and 360 (D, Fig. 90). Similarly if the ship's course is between north and east the number to be signalled is between 0 and 90; east and south, the number is between 90 and 180; south and west the number will be between 180 and 270; west and north the number is between 270 and 360.

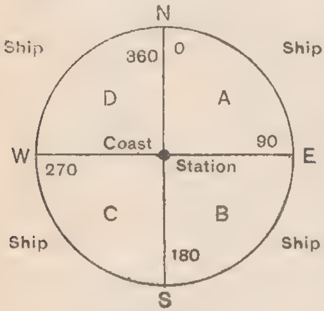


FIG. 90

To facilitate the conversion of bearings and course into the number of degrees to be signalled, a table is given in which either the bearing of the ship from the coast station or the bearing of the coast station from the ship can be looked out and the number of degrees to be signalled seen at a glance.[1] The course must be looked out in the same column as the bearing of the ship from the coast station.

Distress Signal

Ships in distress make use of the following signal :— . . . — — — . . . repeated at short intervals. As soon as a station receives the distress signal it must suspend all correspondence and not resume it until it has made sure that the communication consequent on the call for assistance has been completed. When a ship in distress adds, after a series of distress

[1] See Appendix I.

signals, the call sign of a particular station, the duty of answering the call rests with that station alone. Failing any mention of a particular station any station that receives the call is bound to answer it.

Admiralty Signalling

The signal — . . — . . — . . — indicates that a British man-of-war is calling a British coast station and has a message to transmit to the Admiralty. On receipt of such a signal, the station called must suspend all other business (except that which may concern a vessel in distress) in order to deal with the message from the man-of-war. Any other station (ship or shore) must suspend working so far as may be necessary to ensure satisfactory communication between the man-of-war and the station called.

Controlling Station

The shore station is in all cases the controlling station and arranges order of working.

APPENDIX I

TABLE TO CONVERT BEARING AND COURSE INTO DEGREES

Course or Bearing of Ship from Coast Station		Bearing of Coast Station from Ship		Degrees to be Signalled
North	–	– South	–	– 0°
N. 10° E.	–	– S. 10° W.	–	– 10°
N. 20° E.	–	– S. 20° W.	–	– 20°
30° –	–	– 30°	–	– 30°
40° –	–	– 40°	–	– 40°
50° –	–	– 50°	–	– 50°
60° –	–	– 60°	–	– 60°
70° –	–	– 70°	–	– 70°
80° –	–	– 80°	–	– 80°
East –	–	– West	–	– 90°
S. 80° E.	–	– N. 80° W.	–	– 100°
S. 70° E.	–	– 70°	–	– 110°
60° –	–	– 60°	–	– 120°
50° –	–	– 50°	–	– 130°
40° –	–	– 40°	–	– 140°
30° –	–	– 30°	–	– 150°
20° –	–	– 20°	–	– 160°
10° –	–	– 10°	–	– 170°
South	–	– North	–	– 180°
S. 10° W.	–	– N. 10° E.	–	– 190°
20° –	–	– 20°	–	– 200°
30° –	–	– 30°	–	– 210°
40° –	–	– 40°	–	– 220°

Course or Bearing of Ship from Coast Station	Bearing of Coast Station from Ship	Degrees to be Signalled
50° - -	- 50° -	- 230°
60° - -	60° -	- 240°
70° - -	- 70° -	- 250°
80° - -	- 80° -	- 260°
West -	East	270°
N. 80° W. -	- S. 80° E. -	- 280°
70° -	- 70° -	- 290°
60° - -	- 60° -	- 300°
50° - -	- 50° -	- 310°
40° - -	- 40° -	- 320°
30° - -	- 30° -	- 330°
20° - -	- 20° -	- 340°
10° - -	- 10° -	- 350°
North -	- South -	- 360° or 0°

APPENDIX II

INTERNATIONAL MORSE CODE

Morse Code Signals

Letters:

a · —
ä · — · —
à or å · — — · —
b — · · ·
c — · — ·
ch — — — —
d — · ·
e ·
é · · — · ·
f · · — ·
g — — ·
h · · · ·
i · ·
j · — — —
k — · —
l · — · ·
m — —
n — ·
ñ — — · — —
o — — —
ö — — — ·
p · — — ·
q — — · —
r · — ·
s · · ·
t —
u · · —
ü · · — —
v · · · —
w · — —
x — · · —
y — · — —
z — — · ·

Spacing and length of signals:

1. A bar is equal to 3 dots.
2. The space between the signals which form the same letter is equal to 1 dot.
3. The space between two letters is equal to 3 dots.
4. The space between two words is equal to 5 dots.

Figures:

1	· — — — —
2	· · — — —
3	· · · — —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— — · · ·
8	— — — · ·
9	— — — — ·
0	— — — — —
Bar indicating fraction	— — — — — —

The following signals may also be employed to express figures, but only in official repetitions and in the preamble, and in the text of telegrams written entirely in figures:—

1	· —
2	· · —
3	· · · —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— · · ·
8	— · ·
9	— ·
0	—
Bar indicating fraction	— —

Punctuation and other Signs:

Full stop	(.)	· · · · · ·
Semicolon	(;)	— · — · — ·
Comma	(,)	· — · — · —
Colon	(:)	— — — · · ·
Note of interrogation, or request for the repetition of anything transmitted which is not understood .	(?)	· · — — · ·
Note of exclamation . . .	(!)	— — · · — —
Apostrophe	(')	· — — — — ·
Hyphen or dash	(-)	— · · · · —
Parentheses (before and after the words)	( )	— · — — · —

Inverted commas (before and after each word or each passage placed between inverted commas) ("et")	· — · · — ·
Underline (before and after the words or part of phrase) .	· · — — · —
Call (preliminary of every transmission)	— · — · —
Double dash (=) (signal separating the preamble from the address, the address from the text, and the text from the signature .	— · · · —
Understood	· · · — ·
Error	· · · · · · · · ·
Cross (end of transmission) (+) .	· — · — ·
Invitation to transmit . .	— · —
Wait	· — · · ·
" Received " signal . . .	· — ·
End of work	· · · — · —

APPENDIX III

ABBREVIATIONS AND PHRASES FOR USE BY BRITISH COAST STATIONS AND SHIPS LICENSED BY THE POSTMASTER-GENERAL

THE Radio-Telegraphic Conference of 1906 decided that the International Bureau should be entrusted with the preparation of a list of abbreviations to be used in communication from station to station, according to the form shown below. These abbreviations can at present be used only for communication between British coast stations and ships licensed by the Postmaster-General. But the phrases themselves may, of course, be used when necessary for communication between British Coast Stations and Colonial or Foreign (English-speaking) ships, or between British ships and Colonial or Foreign (English-speaking) coast stations. The French equivalents are also added for use in communication between British coast stations or ships, and non-English-speaking ships or coast stations.

In the use of these abbreviations, the signal employed must be repeated three times, followed by - - —— —— - -

R A What station is corresponding?
Quelle est la station en correspondance?

R B At what distance are you from my station?
A quelle distance vous trouvez-vous de ma station?

R C	What is your wave length in metres? *Quelle est votre longueur d'onde en mètres?*
R D	How many words have you to transmit to me? *Combien de mots avez-vous à me transmettre?*
R E	How are you receiving? *Comment recevez-vous?*
R F	I am receiving badly. *Je reçois mal.*
R G	Send me - - - — - twenty times to regulate my apparatus. *Transmettez-moi vingt fois - - - — - pour régler mes appareils.*
R H	Are you being interfered with? *Etes-vous troublé?*
R J	I am being interfered with. *Je suis troublé.*
R K	Atmospherics are very strong. *Les atmosphériques sont très fortes.*
R L	Tell me the wire charge to . . . *Indiquez-moi la taxe à percevoir pour transmission par fil à . . .*
R M	Engaged with public correspondence. The ship is requested not to interfere. *Correspondance publique est engagée. Prière au navire de ne pas la troubler.*
R N	Stop transmitting. *Cessez votre transmission.*

R Q Transmit more slowly.
Transmettez plus lentement.

R S Increase your power.
Augmentez votre énergie.

R T Diminish your power.
Diminuez votre énergie.

R U Repeat everything.
Répétez tout.

R V from . . . to . . . Repeat from such to such a word.
Répétez de . . . à . . .

R W . . . from . . . Repeat . . . words from . . .
Répétez . . . mots à partir de . . .

R X Your turn is No. . . .
Votre tour est numéro . . .

R Y General call to all stations.

R Z Nothing more.
Rien de plus.

S A I have nothing for you.
Je n'ai rien pour vous.

S B Everything in order.
Tout est en ordre.

S C Wait. I will call you as soon as I have finished.
Attention. Je vous appellerai dès que j'aurai fini.

S D You can transmit faster.
Vous pouvez transmettre plus vite.

S E I am occupied with another station.
Je suis occupé avec une autre station.

If it is found necessary to introduce additional abbreviations they will be continued with the letter S.

APPENDIX IV

AMERICAN MORSE CODE

A . —	O . .	1 . — — .
B — . . .	P	2 . . — . .
C . . .	Q . . — .	3 . . . — .
D — . .	R . . .	4 . . . . —
E .	S . . .	5 — — —
F . — .	T —	6 . . . . . .
G — — .	U . . —	7 — — . .
H	V . . . —	8 — . . . .
I . .	W . — —	9 — . . —
J — . — .	X . — . .	0 ———
K — . —	Y	. . . — — . .
L ———	Z	? — . . — .
M — —	&	! — — — .
N — .		

APPENDIX V

TIME SIGNALS

Time signals are sent out daily at noon and midnight Greenwich mean time by the German station at Norddeich (K.N.D.).

The signals consist of groups of dots (five dots to the group) sent out at seconds intervals. The order of signalling is as follows :—

Preliminary Signals

About	11 h.	53′	0″	Tuning Vs for about 1 or 2 minutes
		57′	50″	— · — · —
			55″	KND
		58′	0″	MGZ (mittlerer Greenwicher Zeit
		58′	40″	— · — · —

Time Signals

	11 h.	58′	46″	First dot of first group
			50″	Last ditto
		58′	56″	First dot of second group
		59′	0″	Last ditto
		59′	6″	First dot of third group
			10″	Last ditto
		59′	36″	First dot of fourth group
			40″	Last ditto
		59′	46″	First dot of fifth group
			50″	Last ditto
		59″	56″	First dot of sixth group
	12 h.	0′	0″	Last ditto
About	12 h.	0′	5″	· — · — ·

Sometimes followed by weather reports.

The wave length used is about 1800 metres.

APPENDIX VI

LIST OF STATIONS TRANSACTING COMMERCIAL BUSINESS

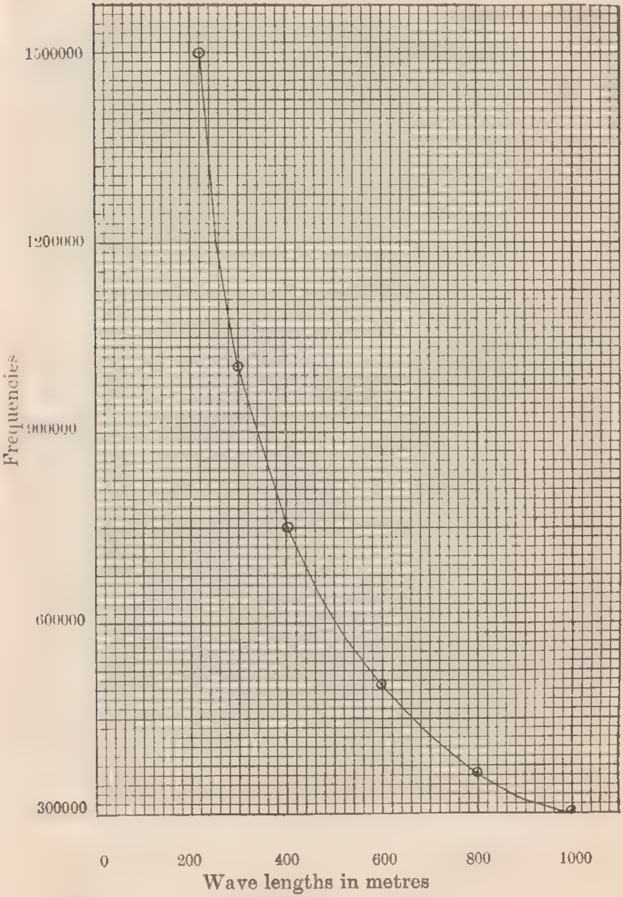
Name of Station	Code Call	Normal Working Distance in Kilometres	Wave Length in Metres	Hours of Attendance
		Belgium		
Nieuport	N P T	100	300	Open always
		Brazil		
Babylonia	B Y N	200	300	
		Denmark		
Copenhagen	G R A	300	300 & 600	
		Germany		
Arkona	K A R	200	600	Open always
Borkum	K B M	175	300	,, ,,
Bulk	K B K	200	300	,, ,,
Cuxhafen	K C X	200	300	,, ,,
Heligoland	K H G	200	600	,, ,,
Marienleuchte	K N R	200	300	,, ,,
Norddeich	K N D	500	600	,, ,,

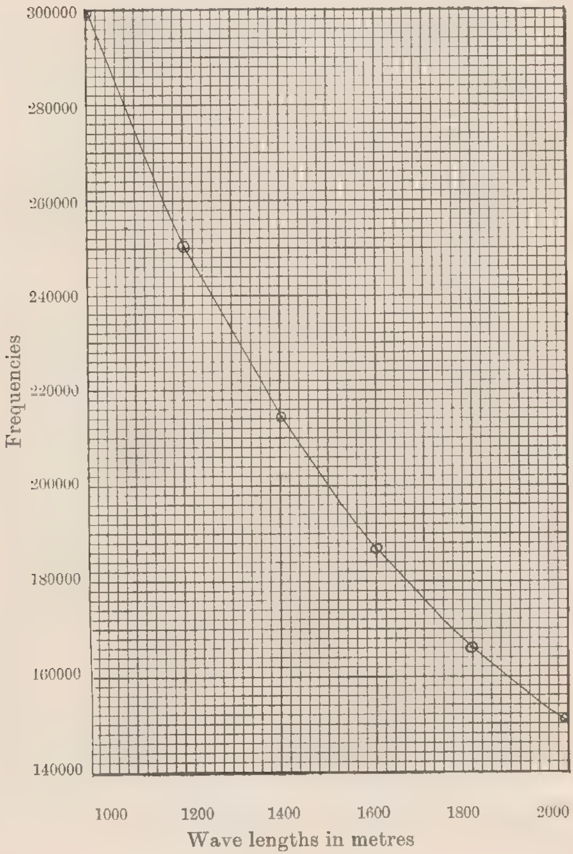
Name of Station	Code Call	Normal Working Distance in Kilometres	Wave Length in Metres	Hours of Attendance
		Great Britain		
Bolt Head	G B A	160	600	Open always
Caister	M C S	120	300	,, ,,
Crookhaven	M C K	400	600	,, ,,
Cullercoats	L N S	500	600	9 A.M. till 9 P.M.
Lizard	M L D	120	300	Open always
Malin Head	M M H	120	300	,, ,,
Niton	M N I	120	300	,, ,,
Rosslare	M R L	120	300	,, ,,
Seaforth, Liverpool	M L V	120	300	,, ,,
		Holland		
Scheveningen	S C H	800	600	Open always
		West Indies		
Jamaica (Bowden)	J C A	200	600	7 A.M. to 7 P.M.
Tobago	T O G	160	600	8 A.M to 4 P.M.
Trinidad	N P G	160	600	8 A.M to 4 P.M.
		Japan		
Chosi	J C S	220	300	Open always
Osizoki	J O S	220	300	,, ,,
Otsuishi	J O I	1000	300	,, ,,
Shiomisoki	J S M	220	300	,, ,,
Tsunoshima	J T S	220	300	,, ,,
		Norway		
Rost	R S T	60	600	
Sorvaagen	S O C	60	600	

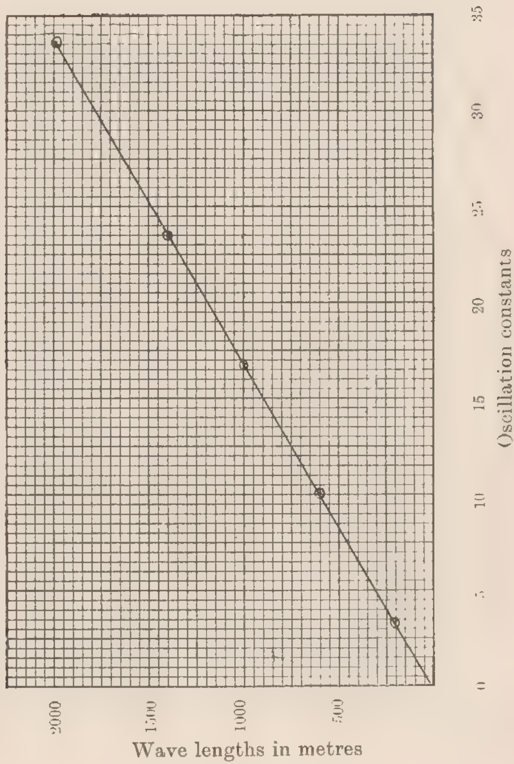
Name of Station	Code Call	Normal Working Distance in Kilometres	Wave Length in Metres	Hours of Attendance
		Uruguay		
Cerro de Montevideo	M V D	500	600	
Punta del este	M M O	500	600	Open always

APPENDIX VII

SHOWING FREQUENCIES AND OSCILLATION CONSTANTS FOR WAVE LENGTHS 0 TO 2000 METRES



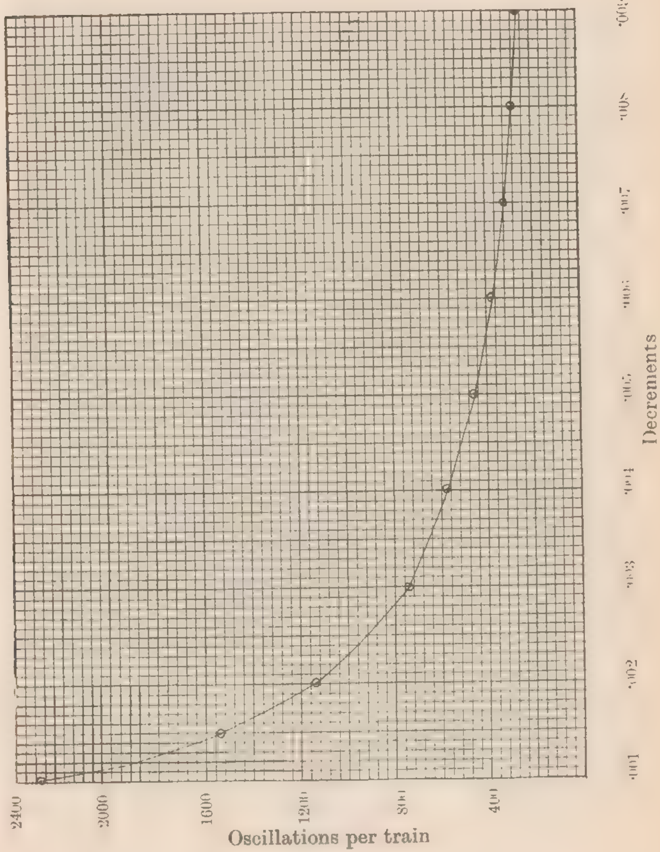

300000
280000
260000
240000
220000
200000
180000
160000
140000
Frequencies
1000
1200
1400
1600
1800
2000
Wave lengths in metres

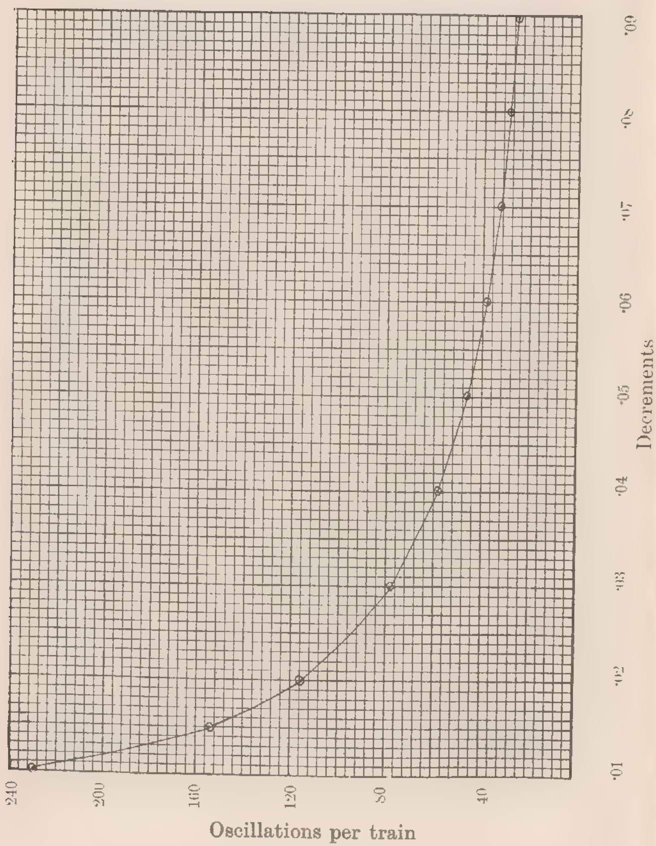

35
30
25
20
15
10
5
0
Oscillation constants
2000
1500
1000
500
Wave lengths in metres

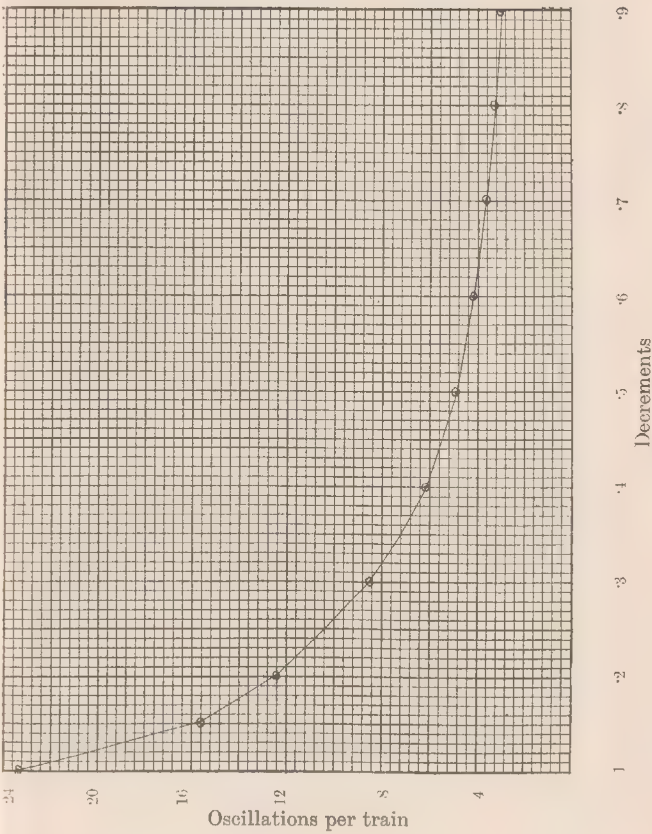
APPENDIX VIII

CURVES SHOWING NUMBER OF OSCILLATIONS PER TRAIN DECREMENTS ·001 TO ·9

WHEN the amplitude of a train of waves has fallen to ·01 of the initial or maximum amplitude, it has for all practical purposes ceased to exist. If the decrement of the oscillation is known the number of oscillations per train can be found from the formula $N = \frac{4 \cdot 605 + \delta}{\delta}$ where N = the oscillations per train 4·605 = the nap log of 100 and δ = the decrement per whole period. If the decrement is reckoned per half period, as is usually the case, the result must be divided by two. The appended curves will show at a glance the number of oscillations per train for decrements from ·001 to ·9.


Decrements
·001
·002
·003
·004
·005
·006
·007
·008
2400
2000
1600
1200
800
400
Oscillations per train


240
200
160
120
80
40
Oscillations per train
·01
·02
·03
·04
·05
·06
·07
·08
·09
Decrements


Decrements
·1
·2
·3
·4
·5
·6
·7
·8
·9
Oscillations per train
24
20
16
12
8
4

APPENDIX IX

WIRE TABLE

H. C. Copper Wires

Size	Diameter	Sectional Area	Resistance at 60 F
S W G	Inch	Sq. inch	Per 1000 yds.
1	·3	·07069	·3469
2	·276	·05083	·4099
3	·252	·04988	·4916
4	·232	·04227	·5801
5	·212	·03530	·6947
6	·192	·02895	·8469
7	·176	·02433	1·008
8	·160	·02011	1·22
9	·144	·01629	1·506
10	·128	·01287	1·906
11	·116	·01057	2·32
12	·104	·00849	2·887
13	·092	·006648	3·684
14	·08	·005027	4·878
15	·072	·004072	6·023
16	·064	·003217	7·622
17	·056	·002463	9·956
18	·048	·001810	13·55
19	·04	·001257	19·51
20	·036	·001018	24·09
21	·032	·000804	30·49
22	·028	·000615	39·82
23	·024	·000452	54·20
24	·022	·000380	64·51
25	·02	·000314	78·05
26	·018	·000254	96·36
27	·0164	·000211	116·1
28	·0148	·000172	142·5
29	·0136	·000145	168·8
30	·0124	·000120	203·1
31	·0116	·000105	232·0
32	·0108	·0000916	267·7
33	·01	·0000785	312·2
34	·0092	·0000665	368·9
35	·0084	·0000554	442·5
36	·0076	·0000454	540·5
37	·0068	·0000363	675·2
38	·006	·0000283	867·3
39	·005	·0000212	1155·
40	·0048	·0000181	1355·

APPENDIX X

UNITS

Practical Units		*Absolute Units*		
Volt	=	10^8	,,	,,
Ampère	=	10^{-1}	,,	,,
Ohm	=	10^9	,,	,,
Watt	=	10^7	,,	,,
Microfarad	=	10^{-15}	,,	,,
Coulomb	=	10^{-1}	,,	,,
Joule	=	10^7	,,	,,
Henry	=	10^9	,,	,,

INDEX

LOG-BOOK

From .... *To* ....

STATION ....

Date	Time	Wave Length		Communicated with	Distance	Strength of Signals	Atmospheric Disturbances	Remarks
		S	R					

STATION ....

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